VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CLVIII.—FEBRUARY, 1882.—VOL. XXVI.

EARTH PRESSURE.

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Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN the October, 1881, and succeeding numbers of this magazine, is published a paper presented to the Institution of Civil Engineers, by Mr. Benjamin Baker, C. E., on "The Actual Lateral Pressure of Earthwork," in which is given an account of a number of direct and indirect experiments on the subject matter, together with Mr. Baker's comments, and comparison of results with a certain theoretical formula, from which it is concluded that the formula gives results much larger than the true ones, even in the ratio of two to one in most cases.

The experiments, some of which were made half a century ago, are very instructive, and should be carefully examined by all engineers who may have occasion to design retaining walls or any kind of structures for resisting the pressure of earthwork.

With this object in view, the writer set to work to test another formula than the one given by Mr. Baker, and with materially different results. This formula includes the friction between the wall and the earth at its back (which is always exerted when a wall moves over and is very appreciable in amount), and is, in one shape or another, the favorite method in use in France and Germany.

The reader is referred to an article by the writer on Retaining Walls, published in the April, 1880, number of this magazine, in which a general formula is found after Weyrauch, from which in turn is deduced for the case of a mass of earth of unlimited slope, Rankine's formula; the direction of the earth thus against a retaining wall is then carefully examined and an attempt made to harmonize the teachings of the two schools, one of which claims that the direction of the earth thrust is always parallel to the top slope of earth, the other claiming that this thrust is inclined at an angle φ of friction of earth on earth, to the normal to the wall. Rankine may be regarded as the originator of the first school, and such men as Scheffler and Winkler as representatives of the second.

It must be observed, at the outset, that all theories are confessedly imperfect, for they suppose the earth *homogeneous* and of the *same density* from top to bottom, *incompressible* too, though it is well known how much embankments shrink, *devoid of cohesion*, *free from water* and *vibrations*, and subject only to the laws of gravity and friction.

So that all we can do is to test our formula, framed from this simple data, by experiments, and see if it can be made to answer the needs of practice, and to what extent.

In the article referred to, the point is made that for a perfectly immovable

wall, and earth that has not settled behind it, the direction and amount of the earth thrust is as given by Rankine; but where the earth has settled appreciably behind the wall, or the wall is on the point of overturning or sliding, then the rubbing of the back of the wall against the earth causes friction, so that the earth thrust must be taken as making an angle φ (or φ' = angle of friction of wall on earth, when $\varphi' < \varphi$) with the normal to the wall.

Let us suppose, *e.g.*, that as the earth is first being deposited against the wall that the thrust by Rankine's formula is exerted. As the earth is filled in, the center of pressure on the base of the wall gradually moves towards the outer toe, causing a greater compression there than elsewhere, and the top of the wall very gradually moves forward, causing friction between the earth and wall at its back, which as gradually increases until its maximum value is attained; at any rate when settling of the earth begins, and this friction will always be exerted at the back of the wall unless destroyed by vibration and rains, or that general consolidation of the bank due to chemical and cohesive affinities, and the compression caused by gravity which manufactures solid clays out of loosely aggregated materials, and often causes the bank even to shrink away from the wall intended to support it. It is evidently then a matter for experiment to decide how much of this friction can be depended on in practice to add to the stability of the wall.

For the corresponding direction of the thrust there is a certain wedge of maximum thrust, different from that for an immovable wall, backed by incompressible materials; the plane of rupture lying nearer the horizontal in the first case than in the last. As a consequence, we shall find that walls that are unstable by Rankine's formula, are perfectly stable by the more correct formula that takes into account this wall friction.

It is to be observed, however, that although the hypothesis of a *plane* surface of rupture has been established, in the article referred to, for the case where the thrust is parallel to the top slope, yet it has not been established for the case where the thrust makes the angle φ or φ' with the normal to the wall, and it is probably incorrect to a certain extent; so that the formula is at best, even for favorable materials (as dry sand devoid of cohesion) only a near approximation.

In steep cuttings, the action of water is constantly bringing down masses of earth whose surface of rupture is curved, more or less vertical at the top and approaching a cycloid somewhat in section.

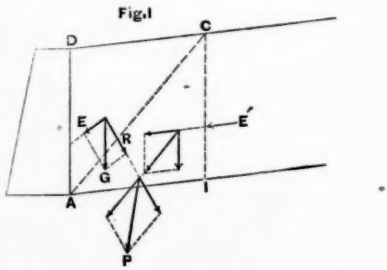
Mr. W. Airy states that he has found a mathematical expression for this curve, but remarks that the constants of cohesion and friction are so variable that its knowledge is of little practical utility.

In the practical formulas, cohesion is neglected, partly on this account and partly because it renders the formula so complex.

If we start out then with such hypotheses as have been stated, which evidently apply, approximately, only to new embankments, and not to old cuttings at all, we may as well for the sake of simplicity assume the surface of rupture *plane*, especially if the results are found to agree sufficiently well with practice.

It was stated in a former article, that supposing the thrust against the wall to be that given by the wall-friction method, that it would be changed in direction

Fig. 1



and intensity as we retreated from the wall, approaching that given by Rankine for a mass of earth of unlimited extent.

Let us first see how this difference in the horizontal components of the thrust is to be provided for.

In the figure, let the straight line AC represent the surface of rupture.

Call the weight of the prism of rupture

ADC, G, the earth thrust against the wall E, and that against the plane of rupture R.

In consequence of the friction exerted against the wall AD by the earth, from their relative movement, the thrust E makes the angle φ' of friction of wall on earth with the normal to the wall, unless φ' is greater than φ, when a thin slice of earth will adhere to the wall, and the friction of this with the adjacent earth will correspond to the angle φ, which is now the angle the thrust makes with the normal.

Similarly the resultant R on the plane AC makes the angle φ to the normal.

So that laying off G = weight of prism ADC, we find E and R by drawing the parallelogram of forces whose sides are parallel to their directions.

By Rankine's method the direction of E would be parallel to $\overline{DC}$, and it will be found that the plane of rupture $\overline{AC}$ lies nearer the vertical, and that the horizontal component of the thrust is larger than in the previous case. It would certainly seem reasonable to suppose that, as we retreat from the wall this horizontal component approaches gradually that given by Rankine for a mass of earth of unlimited extent.

So that on a vertical plane $\overline{CI}$ of the same depth as $\overline{AD}$, the thrust E′, should have a greater horizontal component than E and should be more nearly parallel to $\overline{DC}$. For the object in view it will suffice to combine E′, with the weight of the prism ACI = G and this resultant in turn with R to find the resultant P of the thrust on the plane AI. P is, of course, inclined to the left of the vertical, and its horizontal component is the difference between the horizontal components of E′ and E; so that the surface AI must exert sufficient friction to destroy this difference, which it is perfectly capable of doing; therefore no objection can be urged on the score of an unaccounted-for difference in horizontal thrusts, and the two theories are thus rendered perfectly consistent with each other. If we had assumed E and E′ equal and parallel to the top slope, the resultant pressure on the plane AI would have been vertical; the starting point of Rankine's theory.

This action of the surface AI, in taking up a portion of the horizontal thrust, is analogous to the case of an ordinary road embankment, which, in consequence of symmetry about the plane AD exerts a *horizontal* thrust there. This thrust, when combined with some part of the weight of CAD, gives the final resultant

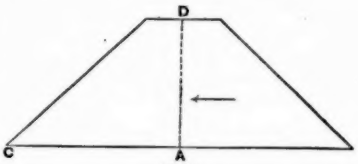


Fig.2

on AC, which ground surface must thus resist by friction the whole of the horizontal thrust.

It may occur to others than Mr. Trautwine (see his Engineer's Pocket Book p. 336) that the proper way to take account of the friction between the earth and wall, is to combine it with the thrust, as given by Rankine, for the total thrust against the wall; but such a resultant thrust will not be found to correspond to any wedge of maximum thrust. The proper direction of the thrust E must be assumed at first and the corresponding wedge of maximum thrust obtained.

The reader is referred to the article in the April, 1880, number of this magazine for a demonstration of the formula applicable. It is proper to state, that Weyrauch, whose general formula we shall adapt to the case in question, agrees with Rankine as to the direction of the earth thrust, at least for the cases examined by him.

In the figure let ABF represent a retaining wall, backed by earth whose top surface is inclined $\varepsilon°$ to the horizontal. The inner face of the wall $\overline{AB}$ is inclined at an angle α to the vertical, which angle is positive in the figure, but negative if AB lies to the right of the vertical through A.

The thrust E acts at $\frac{1}{3}$ AB, above A, and is inclined to the normal to AB at an angle φ', if $\varphi' < \varphi$, otherwise at an angle φ, as hitherto explained.

Weyrauch gives the following construction for finding the plane of rupture $\overline{AC}$: Draw $\overline{BO}$, making the angle $(\alpha +$

φ') with the normal BN to the natural slope AD, then draw a perpendicular $\overline{OA}$ to intersection, with the semicircle described upon $\overline{AD}$ as a diameter, and lay off $\overline{AI}$ equal to $\overline{AH}$, whence $AI=\sqrt{\overline{AO}.\overline{AD}}$; next draw $\overline{IC}$ parallel to $\overline{BO}$ to intersection c with the top slope, when $\overline{AC}$ will be the plane of rupture. The weight of ABC, for a foot in thickness, will give the value of G in a preceding figure, from which E can be found as there explained. On combining E now with W, the weight of the wall acting through its center of gravity, we find S the resultant on the $\overline{AB}$ to where this line intersects the top slope of earth; γ represents the weight per cubic foot of earth.

For the simple case where the back of wall is vertical and the top slope horizontal, we find the expression,

$$E=\frac{\cos\varphi}{2(1+\sin\varphi\sqrt{2})^2}.h^2\gamma \quad . \quad . \quad (2).$$

in which h represents the height from A, vertically to the top surface of earth filling.

We shall now examine some of the experiments recorded by Mr. Baker, and compare "the actual lateral pressure of

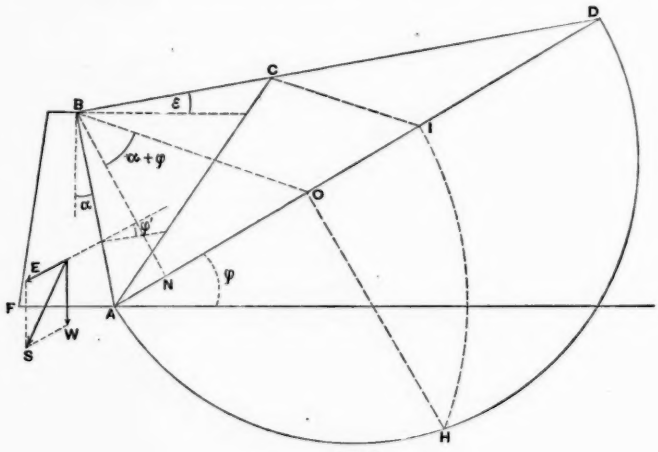


Fig.3

base of the wall; its intersection with $\overline{AF}$ giving the center of pressure on the base.

Instead of the graphical method we may employ the following formulæ for finding the value of the thrust E:

Thus placing

$$\left.\begin{aligned} n&=\sqrt{\frac{\sin(\varphi+\varphi')\sin(\varphi-\varepsilon)}{\cos(a+\varphi')\cos(a-\varepsilon)}} \\ \text{we have}\quad E&=\left(\frac{\cos(\varphi-a)}{1+n}\right)^2\frac{l^2\gamma}{2\cos(a+\varphi')} \end{aligned}\right\} \quad . \quad (1).$$

Bear in mind that when $\varphi'>\varphi$, we must replace φ' in the preceding formulæ by φ. In the formulæ, l represents the inclined height $\overline{AB}$ of the wall, or generally, the distance from A in the direction

earthwork" with the theoretical, as given by the above formulæ.

For brevity let us call the

Height of the wall.....	H
Thickness of the wall.....	t
Weight per cubic foot.....	w
Height of the earth.....	h
Weight per cubic foot.....	γ
Angle of repose of earth.....	φ
Ratio of distance from the center of pressure on the base of wall to outer toe, to the thickness t.....	q
Angle of friction of earth on wall.....	φ'

(Ex. 1). A stable wall of pitch-pine blocks, sustaining a bank of Macadam screenings, level at top. $H=4$, $t=1$,

$w = 46$, $h = 3.75$, $\gamma = 101$, $\varphi = 39°48'$; whence weight of wall=184 lbs.

φ' is not given, but as Rankine gives the angle of friction of timber on stone as 22°, we can say that it lies between 22° and 39°48′, the latter if the projections of the wooden blocks are sufficient to hold any of the filling.

By eq. (1) for $\varphi' = 22°$, we have $n = .824$ and E=136. On combining E, acting at $\frac{1}{3}\,h$ above the base, with the weight of wall, acting at its center of gravity, we find that the resultant cuts the base at the outer toe $\therefore\ q = 0$.

For $\varphi' = \varphi = 39°48'$, we have by eq. (2) E=151, whence by construction $q = 0.16$, the resultant striking within the base.

In (Ex. 2), as in some other cases, a surcharged wall is mentioned, but whether any of the surcharge rests on the wall is not stated, so that computation is useless.

In (Exs. 3 and 4) on the direct lateral thrust of sand, on a board one foot square, as in other experiments of this kind by Mr. Baker, the details of the apparatus are not given, so that it is impossible to say how much the results may be modified by the side friction, acting on the wedge of rupture and perhaps on the board.

The same remark applies to (Exs. 5 and 6) giving by experiment the plane of rupture a little nearer the vertical than theory calls for; besides it is doubtful if the surface of rupture is a plane, when friction at the back of the wall is exerted.

(Ex. 7). This is a valuable experiment by Lieut. Hope, on a wall 20 feet long, built of bricks laid in wet sand. We have here $h = H = 10$, $t = 1.92$, $w = 100$, $\gamma = 95\ 5$, $\varphi = \varphi' = 36°53'$. At the moment of falling the overhang was 4 inches. We have weight of wall 1,920, E=1115 whence $q = .05$, the resultant striking outside of the base. If the wall had been regarded as vertical we should find $q = 0$.

(Ex. 10). Gen'l Pasley experimented with model retaining walls 3 feet long and 26 inches high, backed up with shingle, by measuring the horizontal force applied at the top necessary to pull them over. Here we have, $H = h = 2.17$, $t = 0.67$, $w = 84$, $\gamma = 89$, $\varphi = 39°$, and the horizontal pull at the top, to cause overturning, 30 lbs. We consequently find weight of wall 364 lbs., E=135 lbs. and $q = \frac{1}{8}$.

In the several hundred experiments the thrust of the shingle varied between very wide limits, "16 and 24 lbs.," 17 being the number used by Mr. Baker.

Such variations only show how careful we should be in condemning any formula that may not agree exactly with a particular case.

Gen'l Burgoyne's experimental walls were each 20 feet long, 20 feet high, and a mean thickness of 3 feet 4 inches. The masonry consisted of "rough granite blocks laid dry, and the filling was of loose earth filled in at random without ramming, or other precautions during a very wet winter."

(Ex. 14). One of the walls was 1′ 4″ at top and 5′ 4″ at bottom, the back being vertical. Assuming $w = 142$, $\gamma = 112$, $\varphi = 33°42' = \varphi'$, we find E=5847, weight of wall 9467; whence $q = 0.24$.

The wall was perfectly stable, as the value of q indicates. Of course the wall (Ex. 13) of uniform thickness 3′ 4″ and battered $\frac{1}{2}$″, the height should be stable, judging from the previous case, as more of the material is carried to the rear at the top. Both walls stood easily.

(Ex. 15) describes a wall like (Ex. 14), only turned around, so that the front was vertical. The wall fell by "bursting out" (sliding), at 5′ 6″ from the base and the top descending.

The next wall (Ex. 16) was vertical and fell in the same way, evidently by sliding at about 5 feet above the base, doubtless from the imperfect construction of the rubble work. If the last wall had been a monolithic structure and not moved forward any, the resultant could strike the base $\frac{1}{10}$ diameter inside the base. As it is, it is needless to examine either of the last two experiments for overturning.

(Ex. 17). This wall of Col. Michou's, 40 feet high, with deep *counterforts*, extending back of the face wall 9′ 2″ at top, 2′ 4″ at bottom, 1′ 8″ thick and 5′ from center to center, had a face wall only 1′ 8″ thick, and only fell after the earth was filled in 3 or 4 feet above the top.

"The work was hurriedly constructed during continuous rains with any stones that came to hand, and with very bad lime."

The stability of this wall can only be accounted for in theory, by supposing the

the lateral thrust to cause a binding of the earth between the counterforts, so that this earth may be regarded mostly as a part of the wall. It is really "the most remarkable and interesting" experiment recorded.

This lateral friction, causing a binding of the earth between counterforts close together, certainly adds to the stability of counterforted walls, but how much, experience only can determine. It is on this account that we have not considered other experiments with counterforted walls in a theoretical way.

(Ex. 18). Mr. Constable's experiments on the thrust of peas against wooden bricks, give the following relative data: $H=h=1$, $t=0.4$, $w=1$, $\gamma=2$, $\varphi=27°\ 45'$, whence weight of wall$=4$, and thrust $E=0.32$, thence $q=0.19$, the resultant striking within the base.

"The wall" moved over slightly, but took some amount of jarring to bring it down."

We suspect q is nearer 0.0 than 0.19 for this case, for, as Mr. Baker suggests, a little jarring can easily flatten the slope of repose; besides, the value of φ' is not given, and had to be taken equal to φ, though it is most likely less.

In (Ex. 31), Mr. Baker gives an account of the slightest retaining wall on the underground railway, London, which he finds theoretically unstable, but which is perfectly stable by our theory, the resultant striking the base 0.37 diameter within the base.

The walls previously mentioned have supported new materials placed against them, so that the formulæ should approximately apply, which we find to be the case. But for old ground, thoroughly settled and consolidated by rains, gravity, cohesion, chemical action, &c., it is not pretended that the formulæ apply; it is only experience that can speak here.

Thus, that the strains on the timbering of the gullets (Exs. 26 and 29) were less than theory calls for, is exactly what we should expect. All such facts should be recorded to give the engineer some data to go by. It is well known that solid clay will stand at a vertical slope for some time, even with a house resting on the very edge of the cutting, as seen in digging foundations for adjacent buildings in towns, but by degrees "the weathering" will cause the clay to assume a gentle slope.

In *shafts* the earth would have to break along the surface of a cone of revolution, and since it cannot move in but slightly, we should not expect such a hollow cone of rupture to press with the same force against the timbering, as the wedge of rupture in the case of the ordinary retaining wall.

In *underground* structures, too, the common theory is inapplicable in part, and must be modified to suit the particular case.

Thus, in the figure, let ABFD represent an underground structure of some kind, box drain, arch culvert, or a

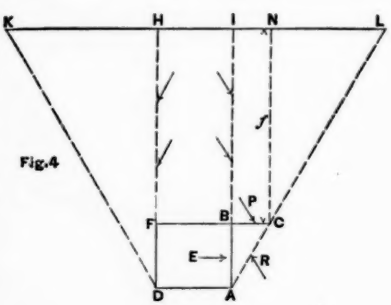


Fig.4

tunnel lining of masonry or timber. If new earth is deposited over the culvert, then it is possible that the whole of the earth HIFB, vertically above the structure, presses on it. But if the culvert settles appreciably, or breaks, then part of the mass of earth above it is upheld by the friction along the sides $\overline{FH}$ and $\overline{BI}$, and its weight is transferred to either side on the principle of the arch.

The actions are very complex, but a rough illustration of the principle involved is given in the writer's "*Voussoir Arches, applied to Stone Bridges, Tunnels, &c.*," p. 121. In the case of a tunnel, driven through the ground, a very large part of the weight is transferred to one side, at least at first, before the timbering or masonry is got in. Old compact ground settles very little after the tunnel arch is completed, but in made ground the vertical pressure on the tunnel may increase after construction.

Let us suppose, *in any case*, that the horizontal thrust E, against the planking $\overline{AB}$ is required to be known.

The thrust per square foot, at a depth $x=\overline{NC}$, is given by the usual formula, $=\gamma x \tan^2\left(45°-\frac{\varphi}{2}\right)$, corresponding to the wedge of maximum thrust ABC of indefinitely small dimensions.

But we perceive at once that the wedge ABC cannot slide towards the left without developing friction along $\overline{BC}$, so that the direction of the thrust P on $\overline{BC}$ must not be taken vertical, but inclined at an angle φ to the left of the vertical. As before, R makes the angle φ with the normal to $\overline{AC}$.

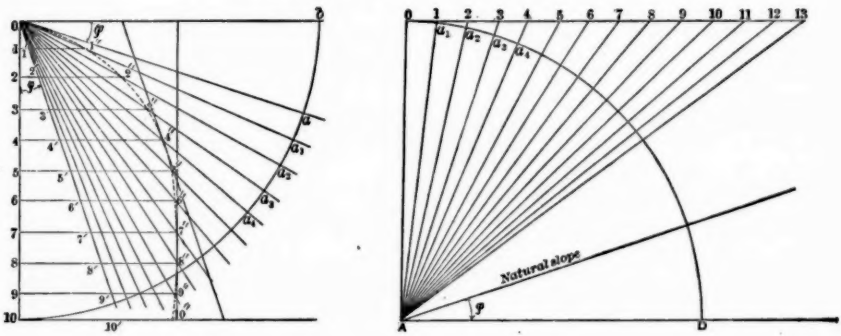
A graphical solution of the case is quickly made.

Thus in the next figure lay off the vertical $\overline{Ao}$ = unity, to represent AB. At o draw the horizontal line $\overline{0-13}$, and lay off $\overline{01}=.1$, $\overline{02}=.2$, ... ; then draw the lines A1, A2, . . . , the arc $\overline{oD}$ with centre A, and the line of natural slope, inclined at the angle φ to the horizontal $\overline{AD}$. Next, in the left figure, describe the quadrant with the the same radius $\overline{Ao}$, and lay off below the horizontal $\overline{ob}$ the angle $boa=\varphi$; then the arcs $\overline{aa_1}$ $\overline{aa_2}$, . . . , equal to the corresponding arcs $\overline{oa_1}$, $\overline{oa_2}$, . . . , in the right figure; so that each of the lines $\overline{oa}$, $\overline{oa_1}$, $\overline{oa_2}$, . . . , in the left figure make the angle φ with the normals to the corresponding planes A0, A1, A2, . . . , in the right figure, and thus represents the direction of the resistances R, offered by each plane in turn, regarded as a plane of rupture.

Next, prick off the distances $\overline{01}$, $\overline{02}$, . . . , on the vertical $\overline{0-10}$, equal to the same distances on the line $\overline{0-13}$ in the right figure, and draw the horizontal lines $\overline{11''}$, $\overline{22''}$, . . . , to intersection with the lines $\overline{oa_1}$, $\overline{oa_2}$, . . . , and with the line $\overline{0-10'}$ draw through o and making the angle φ to the right of the vertical.

Now, as before observed, a certain portion of the weight of earth above the tunnel is transferred to the sides, but its amount cannot be determined; so that we shall take the *vertical component*

Fig. 5



of the pressure on $\overline{BC}$ (preceding figure) equal to the weight of the prism BCIN of earth directly over it $=\gamma x \times \overline{AB}$, for a prism 1 foot thick in a direction perpendicular to the plane of the paper.

This is evidently the minimum value of this component.

This weight, $\gamma . x . \overline{AB}$, is proportional to $\overline{AB}$, so that regarding $\overline{01}$, $\overline{02}$, . . . , as representing these vertical components, we have only to multiply the horizontal thrust obtained by γx to get the lateral pressure in pounds.

In the left figure the lines 01′, 02′, . . . evidently represent the successive values of P for the wedges of thrust, oA1, oA2, . . ., whence the lines 1′ 11″, 2′ 2″, . . ., represent the corresponding values of the horizontal thrust, and the lines

01″, 02,″ . . ., the successive values of R; so that for any wedge of thrust *o*A4, the corresponding forces P, E and R, acting on it, are represented by the lines $\overline{04'}$, $\overline{4'4''}$ and $\overline{4''0}$.

By Coulomb's principle, the largest of the values $\overline{1'1''}$, $\overline{2'2''}$, ..., which in this case is $\overline{4'4''}$=.33, corresponding to the plane of rupture $\overline{A4}$, is the actual pressure exerted, so that in this case where we have taken $\varphi=18°\ 26'$, on a slope of 3 to 1, we get the lateral pressure per square foot exerted at a depth x,

$$.33\times\gamma.x$$

Here we have neglected the weight of the little wedge ABC, which is thus regarded as indefinitely small in all directions, though we have not drawn it so, since exactly the same construction applies, whether we regard it as large or small, provided we neglect its weight.

The intensity of pressure $0.33\gamma.x$ thus found is only at the depth x, and increases directly with x as we go downward.

Observe that if P is taken vertical that we get $88''.\gamma x=.52\gamma x$ as the lateral thrust per unit, exactly as given by Rankine's formula (the place of rupture is now A8), so that considering the friction exerted along the top of the sliding prism, the horizontal thrust is very much diminished; in fact, for a natural slope of 1½ to 1 this lateral pressure is little more than ½ that is deduced from the common formula. We can now understand why the relative stress found to exist by Mr. Baker (Ex. 25) in the timbering of the roof and sides of the heading of the Campden Hill tunnel, was in the ratio of 3.5 to 1 in place of about 2 to 1 as given ordinarily.

Here the heading was driven at a depth of 44 feet from the surface, and the overlying clay, sand and ballast were heavily charged with water, the slope of repose being 3 to 1, "and the full weight of ground taking effect upon the settings."

The construction above was made for this case, and we found the horizontal thrust per square foot=$.33\gamma x$. The vertical pressure per square foot=γx, hence the ratio of the latter to the former is 3 to 1.

We have supposed none of the weight of the material above the tunnel to be transferred to the sides, in which case the ratio would have been larger, as Mr. Baker found.

Having now carefully examined the leading experiments recorded by Mr. Baker, it would seem that we were justified in saying that they agree more nearly with the theory proposed than could have been anticipated, considering the hypothesis on which it is founded.

Cohesion has been neglected altogether, except so far as it is included in taking the angle of frictional repose as equal to that of the same earth endowed with cohesion. There is one experiment recorded though that is inexplicable on any theory, if the pressure was due to weights free to move. Mr. Baker states that he "once applied to a wooden box, full of sand, a pressure equivalent to a column of that material 1,400 feet high before the box burst,"

If the top of the box was free to move as well as the force acting on it, then the wedge of maximum thrust ought to have sheared off and burst the sides of the "little deal box" long before it did.

We shall now continue the investigation by the consideration of such experiments as we happen to have an account of. Mr. Trautwine says (*Engineer's Pocket Book*, p. 333), "that when *not subject to tremor*, a wooden model of a vertical wall, weighing but 28 lbs. per cubic foot and with a base of 35 of its height, balanced perfectly dry sand, sloping at 1½ to 1, and weighing 89 lbs. per cubic foot." He remarks further on: "We cannot understand how correct results are to be expected from experiments like those of Gen. Pasley and others who confined their backing in a box, placing their walls in front of it. The friction of the backing against the sides of the box must diminish the pressure against the wall and thus lead to adopting too slight a thickness.

"We conceive that one experimental wall should diminish in height and thickness each way from its central portion (preserving, however, the same proportion between the two) until it terminates in a point at each end. Ours were made in that way."

These remarks are well put. It may be said though that if the model retaining-wall is long enough, this side friction has less relative effect. Besides, it may be said that in the case of actual walls

this side friction must be experienced before the wall gives, though not generally to the same extent as in the experiments quoted.

Mr. Trautwine does not give the angle of friction of his wooden wall on sand, so that we shall have to assume $\varphi'=22°$, as given in the tables. We have here $H=h=1$ when $t=.35$, $w=28$ $\gamma=89$, $\varphi=33°\ 42$, whence by formula (1) $E=10.9$. The weight of wall is 9.8, and we find $q=.04$ within the base, a very close agreement. The only other experiments we have a record of are given in Curie's *Nouvelle Théorie de la Poussée des Terres*, published in 1870, and *Trois Notes, &c.*, published by the same author in 1873.

These experiments are evidently made with great care, and Curie professes to have upset *l'ancienne théorie*, as he terms the equivalent of the one I am advocating. He takes the thrust causing the greatest moment for *overturning*. This principle would agree with that of Coulomb's maximum thrust, except, perhaps, when the points of application of thrusts corresponding to different wedges were not all at $\frac{1}{3}$ the height as in surcharged walls.

He likewise takes the wedge of rupture that gives the greatest vertical component for the load on the foundation, and the one giving the greatest horizontal component for sliding on the base.

Evidently there is but *one* true thrust, and we think Coulomb's principle establishes it. The same author takes the direction of the thrust against the wall, parallel to the place of rupture, as the particles have a tendency to descend that way, unless this direction makes an angle with the normal to the wall greater than φ' when he squelches the obnoxious component of the "primitive thrust," and makes the little particles of earth next the wall transmit it as best they can to the ground.

Turning to his experiments, we find on page 156 that a vertical wall of wood 0.17 meters high, 0.0485 meters thick and 0.147 meters long, was just at the limit of stability when backed by sand level with the top of the wall, and weighing 1,540 kilograms per cubic meter. The back of the wall was coated with gum covered with sand, as in most of his other experiments, so that $\varphi=\varphi'=35°$. The weight per cubic meter of the wall was 468.5 kilograms. Adapting formula (2) to the French weights and measures, we find

$E=.1249.\times\overline{17}^2\times1540=5.558$ kilograms.

Weight of wall per meter of length $=3.86$ kilograms, whence by the usual construction we find that the resultant passes exactly through the outer toe of wall $\therefore q=0$.

On page 137 is described an experiment with a surcharged brick wall in Portland cement (see figure), whose height was 0.9 meter, thickness 0.23 meter, and length 1.014 meters.

The surcharge extended over the entire top of the wall at a slope of 45°, the natural slope of the sand, to a height of 1.30 meters above the top. The angle of friction of the wall on the sand was $\varphi'=35°$, and the weight per cubic meter of the sand was $\gamma=1260$ kilograms, that of the wall $w=2024$ kilograms. The wall fell when the surcharge was carried to the height indicated.

Having drawn the lines $\overline{A1}$, $\overline{A2}$, $\overline{A3}$,..., to indicate supposable planes of rupture, it is a convenience to reduce the areas of A01, A02, A023, . . . , to that of the triangles A01′, A02′, A03′, . . . , so that the weight of any assumed wedge of rupture, as A024, is equal to $\frac{\overline{A0}\times\overline{04'}}{2}\times\gamma$. We effect this by the common geometrical device of drawing $\overline{11'}\|\overline{A0}$, $\overline{22'}\|\overline{A0}$, $\overline{33''}\|\overline{A2}$ and $\overline{3''3'}\parallel\overline{A0}$, etc., thus reducing each successive triangle to an equivalent one having the same base and altitude.

Next lay off on the vertical $\overline{06}$ of the force diagram on the left the distances $\overline{01}$, $\overline{02}$, $\overline{03}$, . . . , equal to the corresponding distances $\overline{01'}$, $\overline{02'}$, $\overline{03'}$, . . . , in the right figure, and draw through the points 1, 2, 3, . . . , the lines $\overline{11'}$, $\overline{22'}$, . . . , inclined at an angle of $\varphi'=35°$ to the horizontal, to intersection with the lines through o, inclined at an angle φ to the normal to the successive planes of rupture $\overline{A1}$, $\overline{A2}$, . . . , drawn as before explained.

For any supposable prism of rupture then as A024, its weight, the thrust against the wall and that against the plane A4 are in the ratio of the sides of the corresponding triangle in the force

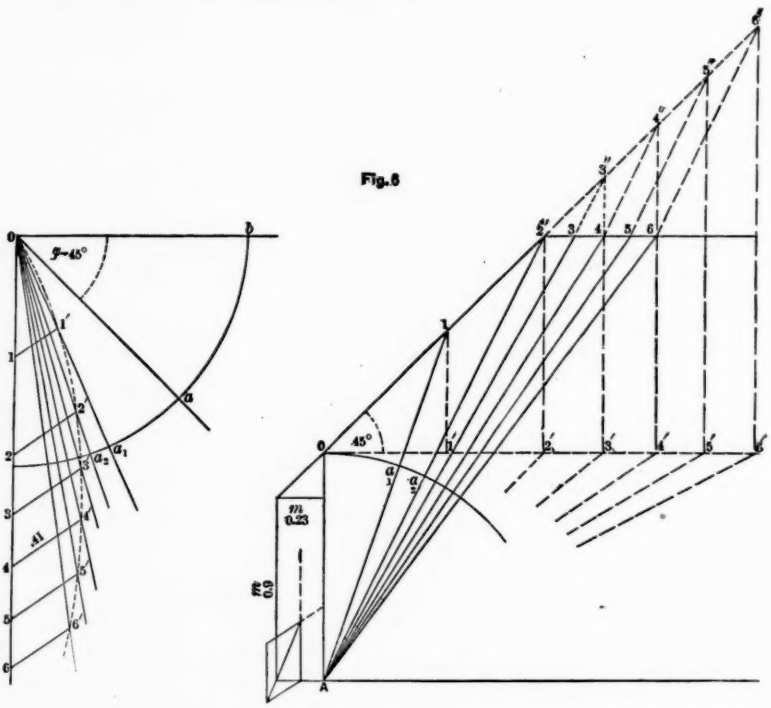
diagram 044′, whose sides are parallel to the direction of these forces. We find the prism corresponding to the greatest thrust to be A024 and the corresponding thrust=44′ (in left Fig.) $\times \frac{A0}{2} \times \gamma = .41 \times \frac{1.13}{2} \times 1260 = 291.8$ kilograms.

The weight of wall and earth over it is equal to 452 kilograms. On combining this weight, acting at the common center of gravity, with the earth thrust acting at $\frac{1}{3}$A0 above A we find that the resultant passes through the outer toe of wall $\therefore q=0$. It is not exact to take the earth thrust as acting at $\frac{1}{3}\overline{A0}$ above A, since A024 is not a triangle, so that the earth thrust does not increase uniformly as we go down from the point 0; still in this particular instance the error is very small since A024 does not differ greatly from the triangle A04″.

When the surcharge is slight, as in the next Figure, it is a nearer approximation to suppose the earth filled in at cD1, $\overline{c\mathrm{D}}$ being drawn parallel to AN the plane of rupture.

The successive planes of rupture, corresponding to different depths below c are now all parallel, so that the earth thrust increases uniformly as we go down and will be proportional to the ordinates parallel to $\overline{\mathrm{AN}}$ of the trapezoid $\overline{c\mathrm{DNA}}$.

Fig. 8



The earth thrust will therefore be applied at a depth below B equal to

$$\frac{2\,\overline{\mathrm{BA}}^3 - \overline{\mathrm{BC}}^3}{3\,\overline{\mathrm{BA}}^2 - \overline{\mathrm{BC}}^2}$$

This is evidently a little above its true position. When the surcharge has intermediate positions the center of pressure on the plane $\overline{\mathrm{A}c}$, will lie between the two positions indicated. Recurring again to the experiments, we find one in the *Trois Notes*, p. 11, represented by the adjoining Figure. Here the frame IBA,

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weighing 53^k, supported the dry sand filling BAc, weighing 1555^k per cubic meter. The length $\overline{AB}$ was one meter, $\overline{AB}$ being the section of a board, one meter square, against which the sand rested. The center of gravity g was determined by experiment.

The angle BAD=27°30 and $\varphi=\varphi'=$ 33°30′, M. Curie finds that "the old theory" would require a base $\overline{A1}=0.^m395$ for stability, whereas his theory calls for $\overline{A1}=0.^m462$. With the latter base it required an "effort of two fingers of each hand to overturn" the frame backed by the sand.

"In consequence of atmospheric humidity (28 Feb. 1873) the sand had retaken a slope of 35°′, and "the overturning was spontaneous though very slow" when the chord A1 was 0.450 meters.

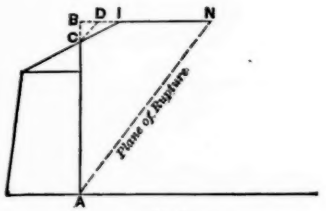


Fig.7

The angle BAD corresponds now to the angle the plane of rupture Ac makes with the vertical $\therefore$ BAD=DAC=$45°-\frac{\varphi}{2}$ =27° 30′.

The thrust on plane AD by Rankine's method is horizontal and equal to 165.4; on combining this with the weight of BAD=318.9, we get the thrust on plane $\overline{AB}$ the same we should find it on plane $\overline{AC}$, so that this thrust is inclined at the angle φ to the normal to $\overline{AB}$; hence in this case the two theories agree. On combining this thrust with the weight of the revetment, we find that the resultant intersects the base $^m.066$ or .15 chord A1 from the point I, a rather larger difference than we have found hitherto for these carefully-made experiments.

In the next experiment the angle BAD was 55° the chord A1, $0^m.545$, and $\varphi=\varphi'$ =33°30′.

M. Curie finds that his theory gives $A1=0^m.565$, very near the actual, whereas "l'ancienne théorie" gives $AI=0^m.423$, a flagrant "désaccord" to which he triumphantly points.

Let us examine this particular application of the ancient theory a little, for in this case if φ was 35°, *the thrust inclined at this angle to* AB, which is itself inclined 55° away from the vertical, would be absolutely vertical, *i.e.*, there would be no horizontal component of the thrust caused by the wedge of rupture BAc, which is evidently absurd. The truth is, the ancient theory no longer applies after passing the plane $\overline{AB}$ inclined at an angle $\left(45-\frac{\varphi}{2}\right)$ with the vertical. We shall prove this by the aid of Rankine's

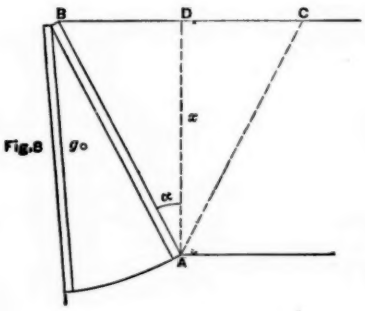


Fig.8

sole principle used in constructing his elegant theory of earth pressure: "*It is necessary to the stability of a granular mass, that the direction of the pressure between the portions into which it is divided by any plane should not, at any point, make with the normal to that plane an angle exceeding the angle of repose.*" Now the old theory, which assumes the direction of the thrust on the wall to make an angle with the normal to the wall equal to φ, would cause the thrust on the plane $\overline{AB}$, inclined at an angle $\left(45-\frac{\varphi}{2}\right)$, with the vertical, to make an angle with the normal to that plane greater than φ, contrary to the principle enunciated.

Let AD=x, and angle BAD=α.

By the usual formula, if the thrust on AD is taken horizontal its value is

$$H=\tfrac{1}{2}\gamma x^2 \tan^2\left(45-\frac{\varphi}{2}\right).$$

The weight of the wedge ABD is

$$W=\tfrac{1}{2}\gamma x^2 \tan a.$$

On combining H with W, we get the true thrust on $\overline{AB}$ when $a>45-\frac{\varphi}{2}$, as we shall show. Let us call d the angle that the thrust on the plane $\overline{AB}$ makes with the normal to that plane:

$$\therefore \tan(a+d)=\frac{W}{H}=\frac{\tan a}{\tan^2\left(45-\frac{\varphi}{2}\right)}.$$

It may be proved that when

$$a>45-\frac{\varphi}{2}, \textit{ that } d<\varphi$$

We have only to verify the inequality

$$\tan(a+\varphi)>\tan(a+d)$$

$$\therefore \frac{\tan(a+\varphi)}{\tan a}>\tan^2\left(45+\frac{\varphi}{2}\right)$$

If the angle,

$$a=\left(45-\frac{\varphi}{2}\right)+\beta,$$

this becomes,

$$\frac{\tan\left(45+\frac{\varphi}{2}+\beta\right)}{\tan\left(45-\frac{\varphi}{2}+\beta\right)}>\tan^2\left(45^\circ+\frac{\varphi}{2}\right)$$

or

$$\tan\left\{\left(45+\frac{\varphi}{2}\right)+\beta\right\}\tan\left\{\left(45+\frac{\varphi}{2}\right)-\beta\right\}>\tan^2\left(45+\frac{\varphi}{2}\right)$$

For brevity placing $\left(45+\frac{\varphi}{2}\right)=x$, we reduce, by the usual formulæ for the tangent of the sum and difference of two angles, the above in equality to

$$\frac{\tan^2 x-\tan^2\beta}{1-\tan^2 x\tan^2\beta}>\tan^2 x$$

Clearing of fractions and transposing, we deduce

$$\tan^4 x>1 \therefore \tan^4\left(45+\frac{\varphi}{2}\right)>1$$

which we know to be true for the values of φ in question.

Now suppose, in accordance with the old theory, we had assumed $d=\varphi$, as usual. Starting with the deduced resistance of the wall we work back, combining it with the wedge of earth lying below the plane inclined $\left(45-\frac{\varphi}{2}\right)$ to the vertical, to get the thrust on that plane, which is thus inclined at a greater angle than φ to its normal; for we have just found that when this inclination was φ that $d<\varphi$, consequently the assump-$d=\varphi$ requires the horizontal component of the thrust to be diminished, which thus causes the thrust on the plane inclined $\left(45-\frac{\varphi}{2}\right)$ to the vertical to make a greater angle than φ with its normal, which is contrary to Rankine's principle.

The resultant of H and W then gives the thrust on the plane AB when a is equal to or greater than $\left(45-\frac{\varphi}{2}\right)$, and the wall in overturning will carry with it a part of the earth, as there is a greater tendency of the earth to slide along the plane inclined $\left(45-\frac{\varphi}{2}\right)$ to the vertical, than below that plane.

Making use now of the revised theory we find in the last example where $a=55^\circ$ that $H=73.86^k$, $W=365.42^k$, which combined with each other and then with the weight of wall 53^k, gives a resultant which strikes the base $^m.009$ or only .017 diameter of base from the very edge.

We have one more experiment to record similar to the last one. In this case (see Curie p. 150) $\overline{AB}=.2$ meter, $\overline{AB}$ representing a square board as before, $a=55^\circ$, $\varphi=\varphi'=35^\circ$ $\gamma=1450$, $w=2.27$, $A1=^m.101$.

We find

$$H=2.59$$
$$W=13.67$$

whence by construction, the final resultant is found to pass only $^m.0065$ or .06 of the chord of the base from the outer toe of the framed revetment.

We shall now give in a little table a condensed summary of our results pertaining to retaining walls *at the limit of stability.*

Authority.	H	t	w	h	γ	φ	φ'	q	Remarks.
	feet.	feet.	lbs.	feet.	lbs.				
Lieut. Hope.	10.	1.92	100	10	95.5	36°53′	36°53′	+.05	Earth level at top.
Gen. Pasley.	2.17	.67	84	2.17	89	39°	39 (?)	−.12	" " "
C. Constable.	1.	.4	1	1	2	27°45′	27°45′ (?)	−.19	" " "
									ratios given.
Trautwine..	1	35	28	1	89	33°42′	22° (?)	+.04	" "
	meters.	meters.	kilog.	meters.	kilog.				
Curie.....	.17	.0485	468.5	.17	1540	35°	35°	.00	Level-topped earth.
"	.90	.23	2024.	2.2	1260	45°	35	.00	Surcharge $1^m.3$ above top of wall.
"	.1148	.114	2.27	1148	1450	35°	35°	−.06	Earth level.
"	.887	.450	53.	.887	1555	35°	35°	−.15	" "
"	.5736	.545	53.	.574	1555	33°30′	33°30′	−.02	" "

Average q—.05.

All the walls were vertical rectangular walls, except the last three which were very light frames of triangular cross section.

The experiments are not of equal value for reasons given, though we have averaged the values of q on that supposition. This average shows that the corresponding resultant passes only five per cent. of the diameter from the outer toe of the base and inside of the same, as the minus sign is meant to indicate. As far as the experiments go, they seem to give faith in the theory as a working theory; still they have generally been made on a small scale and much side friction has probably been developed, except in the case of Trautwine's model, which, singularly enough, agrees in the results with the other experiments.

It will be very beneficial to the profession, if engineers will contribute their knowledge on this subject, and compare the results of their experience with theoretical formulas, so that a good working formula may at last be decided upon.

The experiments have certainly established the fact that the friction at the back of the wall between it and the earth promotes the stability of the wall to a large degree, though it is not improbable that, in some cases, this friction may be lessened or destroyed in walls of large stability, with well settled sand or gravel backing, so that the full thrust, the maximum, as given by Rankine, may be felt.

Certainly it seems that we are justified in saying, that as a rule for *new materials* the actual thrust cannot exceed that given by Rankine, nor generally fall below that found when the whole wall friction is included; so that if we design a wall that is theoretically safe against overturning and sliding on both suppositions, its stability is practically assured.

The wall will not overturn until the whole of the friction at the back of the wall is developed, according to the experiments; so that if we adopt the European plan of taking the thrust E as double that given by formulæ (1) or (2) in *designing* a wall, its stability is assured, at least. It is said for good foundations that the results agree with those of Vauban, whose retaining walls have stood the test of time, though failures have been recorded in this country for some walls designed by such a formula.

It would seem more scientific and satisfactory every way, to require that the resultant of the thrust as given by formulæ (1) or (2), should pass a certain proportion of the base from the outer toe. If this proportion is assured $= \frac{1}{3}$, then there will be only compressive stress exerted at the base, which it seems to me desirable, especially when the mortar is green, as it prevents any joints opening at the back of the wall. The resultant could pass much nearer the outer toe, so far as crushing of the material there is to be guarded against.

Let us see what this requirement will lead to.

Thus take a vertical rectangular wall 10 feet high, backed by earth level with the top, whose angle of repose is $\varphi = 33°42$, corresponding to the slope of $1\frac{1}{2}$ to 1. The thrust is, when γ is taken equal to unity,

$$E=\frac{100}{2}\frac{\cos\varphi}{(1+\sin\varphi\sqrt{2})^2}=13.1$$

the relative weight of wall is $10\times3\frac{1}{3}\frac{w}{\gamma}$.

Now a construction on a large scale will show that in order that the resultant on the base strikes it one-third of its diameter back from the outer edge, that this ratio $\frac{w}{\gamma}$ of specific weights of masonry and earth should equal 1.095; or practically the weight per cubic foot of the masonry should be one and one-tenth times that of the earth—a perfectly *safe* proportion, as a rule.

The proportion of $\frac{1}{3}$ for height to base is what Mr. Baker gives as the result of his own extensive experience; and he says further, that "it has been similarly proved by experiment, that under no ordinary conditions of *surcharge* or *heavy backing*, is it necessary to make a retaining wall on a solid foundation, more than $\frac{1}{2}$ the height in thickness."

Let us examine this limit theoretically, by considering a vertical rectangular wall, 10 feet high and 5 feet thick *surcharged* entirely over the top with earth, sloping indefinitely at the angle of repose $1\frac{1}{2}$ to 1, the most unfavorable conditions for stability.

We have here $\varepsilon=\varphi$, and the formula we have been using reduces to that given by Rankine,

$$E=\frac{h^2}{2}\cos 33°42'.$$

Successive trials showed us that for $\frac{w}{\gamma}=1.1$, and in order that the resultant on the base pass exactly $\frac{1}{3}$ diameter of the base from the outer toe that the thickness of the wall should be a little more than .8 of its height; so that for a wall 10 feet high and 8 feet thick, *entirely* covered with the surcharge, the value of h in the formula above equals 15.33, whence E=97.76, and acts at 5.11 feet above the base, and the weight of wall $8\times10\times1.1=88$.

A construction will now show the facts above stated, and further, that the resultant on the base is inclined 30° to the vertical, so that the wall must slide if resting on clay (angle of friction with dry clay is 27°) unless the earth in front of it can resist it, or the foundation courses are made more inclined to the horizontal. This result does not agree at all with the thickness given as the limit by Mr. Baker. There is a choice to be made evidently, and as one experiment of Curie's on a surcharged wall exactly sustained the theory, it seems that we must seek elsewhere for the discrepancy.

Is it not that constructors do not use the same factor of safety for walls with high surcharges as for walls with earth level with their top?

Or is not the retaining wall, as built, at last a compromise between the two theories, which differ considerably for level-topped earth, and gradually approach each other as the top slope nears the angle of repose?

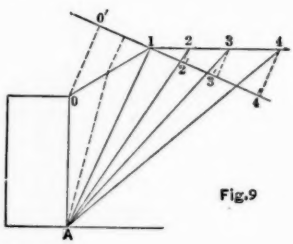


Fig. 9

If the latter, then it seems useless to frame a table on either theory to work by, except as indicating reasonable limits.

We give below some approximately correct tables, that are made out on the supposition that the specific gravity of the masonry is 1.1 times that of the earth (*safe* for brick walls backed by sand or rock walls with the heaviest earth filling), and that the resultant on the base passes $\frac{1}{3}$ of its diameter from the outer toe, using the theory which includes the whole of the friction at the back of wall.

In the first table the surcharge is supposed to extend from o backwards, at the natural slope ($1\frac{1}{2}$ to 1), until the level plane $\overline{14}$ is attained.

The figure shows the neatest way of laying off the equivalent triangles having the same base $\overline{A1}$, by drawing parallels to $\overline{A1}$ through 0, 2, 3, 4, . . to intersection with the perpendicular to $\overline{A1}$ through

1. Thus the area of A014A is replaced by ‡A0′4′A; so that by using the distances 0′1, 0′2′, . . . , on the force diagram, to represent the weight of the earth prisms, we have simply to multiply the value of E, given by construction, by $\frac{1}{2}$ of $\overline{A1} \times \gamma$.

The plane of rupture will always be found to the right of $\overline{A1}$, so that it is needless to draw any planes to the left.

The first column in the table (h') gives the ratio of the height of the top of the surcharge above the top of the wall to the height of the wall; the next, the thickness of the wall (t) for height 1; and the third column (i), the inclination of the resultant on the base (which passes $\frac{1}{3}$ diameter from outer edge) to the vertical.

Those quantities marked with a star were found by actual trial, the balance interpolated.

SURCHARGE COMMENCING AT BACK OF WALL.

h'	t	$i°$	h'	t	$i°$
0	.33*	14°	.4	.44	
.1	.38		.5	.45*	18°
.2	.41		.7	.46	
.25	.42*	15°	1.0	.48	
.3	.43		∞	.48*	24°

The next table is very roughly interpolated from four actual cases marked with a star.

The surcharge now extends over the entire top of the wall at the slope of $1\frac{1}{2}$ to 1, the angle of repose assumed, until it meets the level plane.

As before, $\frac{w}{\gamma} = 1.1$, $\varphi = \varphi' = 33°42'$, $q = \frac{1}{3}$.

SURCHARGE EXTENDING OVER TOP OF WALL.

h'	t	$i°$	h'	t	$i°$
.0	.33*	14°	.8	.69*	20°
.2	.44		1.	.74	
.4	.53*	17°	1.5	.80	
.6	.62		∞	.82*	30°

The earth resting on the top of the wall was not considered, though it does help by its weight to a small extent.

Especial attention is called here to the rge inclinations to the vertical of the resultant on the base.

A number of the walls would not stand on dry clay, and with wet clay whose angle of friction with masonry is only $18\frac{1}{4}°$, how many of the walls would slide as soon as the foundation was saturated with water?

It seems folly not to incline the joints of the lower courses of a retaining wall to obviate this sliding, which is really more to be feared in the majority of cases of actual walls than overturning. This is especially true of dock walls, though it seems to have been least of all considered in construction, if we are to judge from the numerous sections of actual structures given by Mr. Baker.

Turning now to Mr. Trautwine's "Engineer's Pocket Book," p. 334, we find a table of thicknesses of retaining walls for various surcharges, as deduced from some rough experiments with wooden walls and sand backing.

For the vertical rectangular wall, with earth level at top, he gives the thickness, .35 the height; but for a surcharge of indefinite slope starting at the back of the wall as much as .68 the height, in place of the .48 found above. This is probably due to the fact that he did not coat the back of his retaining walls with sand, thus causing the earth thrust to take a more nearly horizontal direction.

We have seen in the case of the experiment of Curie's, of a brick wall, coated with Portland cement and having a high surcharge, that $\varphi' = 35°$ whilst φ was 45°.

The theory exactly applied here, taking the thrust as inclined at the angle $\varphi' = 35°$ with the horizontal, though it would have indicated quite a stable wall if φ' had been assumed equal to $\varphi = 45°$.

The table quoted by Trautwine from Poncelet is sensibly erroneous for high surcharges, as Scheffler has shown, owing to the approximations introduced by Poncelet in his formulæ, and especially the error of taking the thrust as horizontal against the wall.

Any of the dimensions given can be tested by computation, or by the *graphical* construction already illustrated, a method that will put the average reader in full possession of the means to test the stability, in a sufficiently precise manner, of any kind of retaining wall,

sustaining any character or shape of backing; and besides has the advantage of keeping before the eyes of the investigator the hypotheses upon which his theory is founded, so that the theory may not be applied erroneously.

NOTES ON THE BEST METHOD OF MEETING THE SANITARY REQUIREMETS OF COLONIAL TOWNS.

By EDWARD DOBSON, M. Inst. C.E.

From Abstracts of Institution of Civil Engineers.

THE author's remarks are applicable to new towns, as distinguished from closely built towns in the old World.

In planning new towns favorable conditions may be secured by legislative enactment, which are unattainable where the ground has been closely built upon without regard to sanitary requirements.

Each dwelling should have a supply of water of not less than 20 gallons per day per inmate, exclusive of the quantity required for flushing closets. If rain water is to be stored the tanks should be covered so as to exclude the sun's rays, the light and heat of which have a powerful effect in promoting vegetable growth. Every dwelling should have a properly constructed receptacle for ashes and kitchen refuse. Sunk cesspools for excreta should be strictly prohibited within the boundary of every township. Ash-middens may be adopted, that is a privy and ash-heap may be combined, if the floor be paved and slightly raised above the general surface of the ground, and a drain be laid to carry off any liquid not absorbed by the ashes; or movable pans or pails may be adopted, if fitted with air-tight lids for use during removal, and disinfected before they are replaced. But in all cases, whether of receptacles for refuse, ash-middens, or movable pans, they should be compulsorily emptied at short intervals under municipal regulations.

Water closets may be adopted, under certain circumstances, but their introduction involves a considerable amount of municipal organization, for the double purpose of providing a water supply for flushing them and a system of underground drains for the removal of the excreta; whereas, if either of the other systems be adopted, it is only the house slops which require to be drained away, and they may be drained into the street gutters if these be kept constantly flushed by an efficient water supply. The author does not approve of water closets in new towns, inasmuch as the drains in connection with them disseminate infectious disease, and he asks whether it is not a solemn duty to resist the introduction of an evil which conduces to the lowering of the physical standard of the future population.

In almost every district there will be found channels by which the water of heavy rainfalls passes off to lower levels. Instead of blocking up these natural channels, as is too often done in the formation of streets, they should be utilized, straightened, deepened and connected with suitable outfalls to the river. When the lines of drainage have been marked out the storm water channels reserved, and the position and levels of the outfalls defined, and not before, the streets of the town may be laid out, taking care in doing so to grade the streets in such manner that the surface water on every property may drain into the street gutters, and these into the outfall. In a new country the work of the engineer should precede, and not follow, that of the settlement surveyor; and until this principle is recognized, and acted upon by colonial governments, the history of colonial progress will always be a record of costly struggles to regain facilities of communication, drainage and water supply, which have been heedlessly sacrificed by handing over the Crown lands to private ownership, without due reservation of conditions essential to the general welfare of the community.

SOME OF THE DEVELOPMENTS OF MECHANICAL ENGINEERING DURING THE LAST HALF CENTURY.

By SIR FREDERICK BRAMWELL, V.P. Inst. C E., F.R.S.

From the "Journal of the Society of Arts."

I AM quite sure the section will agree with me in thinking, it was very fortunate for us, and for science generally, that our President refrained from occupying the time of the section by a retrospect, and devoted himself, in that lucid and clear address with which he favored us, to the consideration of certain scientific matters connected with engineering, and to the foreshadowing of the directions in which he believes it possible that further improvements may be sought for. But I think it is desirable that some one should give to this section a record, even although it must be but a brief and imperfect one, of certain of the improvements that have been made, and of some of the progress that has taken place, during the last fifty years, in the practical application of mechanical science, with which science and its applications our section is particularly connected. I regret to say that, like most of the gentlemen who sat on this platform yesterday, who, I think, were, without exception, past presidents of the section. I am old enough to give this record from personal experience. Fifty years ago I had not the honor of being a member, nor should I, it is true, have been eligible for membership of the Association; but I was at that time vigorously making models of steam-engines, to the great annoyance of the household in which I lived, and was looking forward to the day when I should be old enough to be apprenticed to an engineer. Without further preface, I will briefly allude to some of the principal developments of a few of the branches of engineering. I am well aware that many branches will be left unnoticed; but I trust that the omissions I may make will be remedied by those present who may speak upon the subject after me.

I will begin by alluding to the *steam-engine employed for manufacturing purposes.* In 1831, the steam-engine for these purposes was commonly the condensing beam engine, and was supplied with steam from boilers, known, from their shape, as wagon boilers; this shape appears to have been chosen rather for the convenience of the sweeps, who periodically went through the flues to remove the soot consequent on the imperfect combustion, than for the purpose of withstanding any internal pressure of steam. The necessary consequence was, that the manufacturing engines of those days were compelled to work with steam of from only 3½ lbs to 5 lbs. per square inch of pressure above atmosphere. The piston speed rarely exceeded 250 feet per minute, and as a result of the feeble pressure, and of the low rate of speed, very large cylinders indeed were needed relatively to the power obtained. The consumption of fuel was heavy, being commonly from 7 lbs. to 10 lbs. per gross indicated horse power per hour. The governing of the engine was done by pendulum governors, revolving slowly, and not calculated to exert any greater effort than that of raising the balls at the end of the pendulum arms, thus being, as will be readily seen, very inefficient regulators. The connection of the parts of the engine between themselves was derived from the foundation upon which the engine was supported. Incident to the low piston speed, was slowness of revolution, rendering necessary heavy fly-wheels, to obtain even an approach to practical uniformity of rotation, and frequently rendering necessary also heavy trains of toothed graining, to bring up the speed from that of the revolutions of the engine to that of the machinery it was intended to drive.

In 1881, the boilers are almost invariably cylindrical, and are very commonly internally fired, either by one flue or by two; we owe it to the late Sir William Fairbairn, President of the British Association in 1861, that the danger, which at one time existed, of the collapse of these fire flues, has been entirely removed by his application of circumferential

bands. Now-a-days there are, as we know, modifications of Sir William Fairbairn's bands, but by means of his bands, or by modifications thereof, all internally flued boilers are so strengthened that the risk of a collapse of the flue is at an end. Boilers of this kind are well calculated to furnish—and commonly do furnish—steam of from 40 lbs. to 80 lbs. pressure above atmosphere. The piston speed is now very generally 400 feet or more, so that, notwithstanding that there is usually a liberal expansion, the mean pressure upon the piston is increased, and this, coupled with its increased speed, enables much more power to be obtained from a given size of cylinder than was formerly obtainable. The revolutions of the engine now are as many as from 60 to 200 per minute, and thus, with far lighter fly-wheels, uniformity of rotation is much more nearly attained. Moreover, all the parts of the engine are self-contained; they no longer depend upon the foundation, and in many cases the condensing is effected either by surface condensers, or, where there is not sufficient water, the condensation is, in a few instances, effected by the evaporative condenser—a condenser which, I am sorry to say, is not generally known, and is therefore but seldom used, although its existence has been nearly as long as that of the Association. Notwithstanding the length of time during which the evaporative condenser has been known to some engineers, it is a common thing to hear persons say, when you ask them if they are using a condensing engine, "I cannot use it; I have not water enough." A very sufficient answer indeed, if an injection condenser, or an ordinary surface condenser, constituted the sole means by which a vacuous condition might be obtained; but a very insufficient answer, having regard to the existence of the evaporative condenser, as by its means, whenever there is water enough for the feed of a non-condensing engine, there is enough to condense, and to produce a good vacuum. The evaporative condenser simply consists of a series of pipes, in which is the steam to be condensed, and over which the water is allowed to fall in a continuous rain. By this arrangement there is evaporated from the outside of the condenser a weight of water which goes away in a cloud of vapor, and is nearly equal to that which is condensed, and is returned as feed into the boiler. The same water is pumped up and used outside the condenser, over and over, needing no more to supply the waste than would be needed as feed water. Although this condenser has, as I have said, been in use for thirty or forty years, one still sees engines working without condensation at all, or with water-works water, purchased at a great cost, and to the detriment of other consumers, who want it for ordinary domestic purposes; or one sees large condensing ponds made, in which the injection water is stored, to be used over and over again, and frequently (especially towards the end of the week) in so tepid a state as to be unfit for its purpose. The governing is now done by means of quick-running governors, which have power enough in them to raise not merely the weight of the pendulum ball, which is now small, but a very heavy weight, and in this way the governing is extremely effective. I propose to say no more, looking at the magnitude of the whole of my subject, upon the engine used for manufacturing purposes, but rather to turn at once to those employed for other objects.

Steam navigation.—In 1831, there was a considerable number of paddle steamers running along some of the rivers in England, and across the Channel to the Continent. But there were no ocean steamers, properly so-called, and there were no steamers used for warlike purposes. As in the case of the wagon boilers, the boilers of the paddle steamers of 1831 were most unsuited for resisting pressure. They were mere tanks, and there was as much pressure when there was no steam in the boiler from the weight of the water on the bottom, as there was at the top of the boiler from the steam pressure when the steam was up. Under these circumstances again, from $3\frac{1}{2}$ lbs. to 5 lbs. was all the pressure the boilers were competent to bear, and as the engines ran at a slow speed, they developed but a small amount of horse-power in relation to their size. Moreover, as in the land engine, the connection between the parts of the marine engine was such as to be incompetent to stand the strain that would come upon it if a higher pressure, with a considerable

expansion, were used, and thus the consumption of coal was very heavy; and we know, that having regard to the then consumption, it was said on high authority, it would be impossible for a steamboat to traverse the Atlantic, as it could not carry fuel enough to take it across; and indeed it was not until 1838 that the Sirius and Great Western did make the passage. The passage had been made before, but it was not until 1838 that the passenger service can be said to have commenced. In 1831, the marine boiler was supplied with salt water, the hulls were invariably of wood, and the speed was probably from eight to nine knots an hour. In 1881, the vessels are as invariably either of iron or of steel, and I believe it will not be very long before the iron disappears, giving place entirely to the last-mentioned metal. With respect to the term "steel," I am ready to agree that it is impossible to say where, chemically speaking, iron ends and steel begins. But (leaving out malleable cast iron) I apply this term "steel" to any malleable ductile metal of which iron forms the principal element, and which has been in fusion, and I do so in contradistinction to the metal which may be similar chemically, but which has been prepared by the puddling process. Applying the term steel in that sense, I believe, as I have said, it will not be very long before plate iron produced by the puddling process will cease to be used for the purpose of building vessels. With respect to marine engines, they are now supplied with steam from multiple-tubed boilers, the shells of which are commonly cylindrical. They are of enormous strength, and made with every possible care, and carry from 80 lbs. to 100 lbs. pressure on the square inch. It has been found, on the whole, more convenient to expand the steam in two or more cylinders, rather than in one. I quite agree that, as a mere matter of engineering science, there is no reason why the expansion should not take place in a single cylinder, unless it be that a single cylinder is cooled down to an extent which cannot be overcome by jacketing, and which, therefore, destroys a portion of the steam on its entering into the cylinder. As regards the propeller, as we know, except in certain cases, the paddle wheel has practically disappeared, and the screw propeller is all but universally employed. The substitution of the screw propeller for the paddle enables the engine to work at a much higher number of revolutions per minute, and thus a very great piston speed, some 600 ft. to 800 ft. per minute is attained; and this, coupled with the fairly high mean pressure which prevails, enables a large power to be got from a comparatively small-sized engine. Speed of fifteen knots an hour are now in many cases maintained, and on trial trips are not uncommonly exceeded. Steam vessels are now the accepted vessel of war. We have them in an armored state, and in an unarmored state, but when unarmored rendered so formidable, by the command which their speed gives them of choosing their distance, as to make them, when furnished with powerful guns, dangerous opponents even to the best armored vessels. We have also now marine engines, governed by governors of such extreme sensitiveness as to give them the semblance of being endowed with the spirit of prophecy, as they appear rather to be regulating the engine for that which is about to take place than for that which is taking place. This may sound a somewhat extravagant statement, but it is so nearly the truth, that I have hardly gone outside of it in using the words I have employed. For a marine governor to be of any use, it must not wait until the stern of the vessel is out of the water before it acts to check the engine and reduce the speed. Nothing but the most sensitive and, indeed, anticipatory action of the governors can efficiently control marine propulsion. Instances are on record of vessels having engines without marine governors being detained by stress of weather at the mouth of the Thames, while vessels having such governors, of good design, have gone to Newcastle, have come back, and have found the other vessels still waiting for more favorable weather, With respect to the condensation in marine engines, it is almost invariably effected by surface condensers, and thus it is that the boilers, instead of being fed with salt water as they used to be, involving continuous blowing off, and frequently the salting up of the boiler, are now fed with distilled water. It should be noticed, however, that in some instances, owing to the absence of a thin

protecting scale upon the tubes and plates, very considerable corrosion has taken place when distilled water, derived from condensers having untinned brass tubes, has been used, and where the water has carried into the boiler fatty acids, arising from the decomposition of the grease used in the engine; but means are now employed by which these effects are counteracted.

I wish, before quitting this section of my subject, to call your attention to two very interesting, but very different, kinds of marine engines. One is the high speed torpedo vessel, or steam launch, of which Messrs. Thornycroft's firm have furnished so many examples. In these, owing to the rate at which the piston runs to the initial pressure of 120 lbs., nnd to very great skill in the design, Messrs. Thornycroft have succeeded in obtaining a gross indicated horse power for as small a weight as half a cwt., including the boiler, the water in the boiler, the engine, the propeller shaft and the propeller itself.

To obtain the needed steam from the small and light boiler, recourse has to be made to the aid of a fan blast driven into the stokehole. From the use of a blast in this way advantages accrue. One is, as already stated, that from a small boiler a large amount of steam is produced. Another is that the stokehole is kept cool; and the third is that artificial blasts thus applied are unaccompanied by the dangers which arise, when under ordinary circumstances the blast is supplied only to the ashpit itself. The second marine engine to which I wish to call your attention is one that has been made with a view to great economy. The principles followed in its construction are among those suggested by the President (Sir W. G. Armstrong) in his address. He, you will remember, pointed out that the direction in which economy in the steam engine was to be looked for was that of increasing the initial pressure; although at the same time he said that there were drawbacks in the shape of greater loss, by radiation, and by the higher temperature at which the products of combustion would escape. We must admit the fact of the latter source of loss, when using very high steam, it being inevitable that the temperature of the products of combustion escaping from a boiler under these conditions must be higher than those which need be allowed to escape when lower steam is employed; although I regret to say that in practice, in marine boilers working at comparatively low pressures, the products are ordinarily suffered to pass into the funnel at above the temperature of melted lead. But with respect to the loss by radiation in the particular engine I am about to mention—that of Perkins—there is not as much loss as that which prevails in the ordinary marine boilers, because the Perkins boiler is completely enclosed, with the result that while there is within the case a boiler containing steam of 400 lbs. on the square inch, and the fire to generate that steam, the hand may be applied to the casing itself, which contains the whole of the boiler, without receiving any unpleasant sensation of warmth. By Mr. Perkins' arrangement, using steam of 400 lbs. in the boiler, it was found, as the result of very severe trials, conducted by Mr. Rich, of Messrs. Easton and Anderson's firm, and myself—trials which lasted for twelve hours—that the total consumption of fuel, including that for getting up steam from cold water, was just under 1.8, actually 1.79 lbs. per gross indicated horse power per hour. That gross indicated horse power was obtained in a manner which it is desirable should always be employed in steamboat trials. It was not got by using as a divisor the horse power of the most favorable diagram obtained during the day; but it was got from diagrams taken during the regular work; then, every half-hour, when the pressure began to die down from coal being no longer put upon the fire, diagrams taken every quarter of an hour, and then, towards the last, every five minutes; and the total number of foot pounds were calculated from these diagrams, and were used to obtain the gross indicated horse power.

Further, so far as could be ascertained by the process of commencing a trial with a known fire, and closing that trial at the end of six hours, with the fire as nearly as possible in the same condition, the consumption was 1.66 lbs. of coal per gross indicated horse power per hour. So that, without taking into account the coal consumed in raising steam from cold water, the engine worked for $1\frac{2}{3}$ lbs. of coal per horse per hour. I think

it well to give these details, because undoubtedly it is an extremely economical result. Our President alluded to the employment of ether as a means of utilizing the heat which escaped into the condenser, and gave some account of what was done by Mons. Du Tremblay in this direction. It so happened that I had occasion to investigate the matter at the time of Du Tremblay's experiments; very little was effected here in England, one difficulty being the Excise interference with the manufacture of ether. Chloroform was used here, and it was also suggested to employ bi-sulphide of carbon. In France, however, a great deal was done. Four large vessels were fitted with the ether engines, and I went over to Marseilles to see them at work. I took diagrams from these engines, and there is no doubt that, by this system, the exhaust steam from the steam cylinder, which was condensed by the application of ether to the surface of the steam condenser (producing a respectable vacuum of about 22 inches), gave an ether pressure of 15 lbs. on the square inch above atmosphere, and very economical results as regards fuel were obtained. The scheme was, however, abandoned from practical difficulties. It need hardly be said that ether vapor is very difficult to deal with, and although ether is light, the vapor is extremely heavy, and if there is any leakage, it goes down into the bilges by gravitation, and being mixed with air, unless due care is taken to prevent access to the fires, there would be a constant risk of a violent explosion. In fact, it was necessary to treat the engine room in the way in which a fiery colliery would be treated. The lighting, for instance, was by lamps external to the engine room, and shining through thick plate glass. The hand lamps were Davy's. The ether engine was a bold experiment in applied science, and one that entitles Du Tremblay's name to be preserved, and to be mentioned as it was by our President. There was another kind of marine engine that I think should not be passed over without notice; I allude to Howard's quicksilver engine. The experiments with this engine were persevered in for some considerable time, and it was actually used for practical purposes in propelling a passenger steam vessel called the Vesta, and running between London to Ramsgate. In that engine the boiler had a double bottom, containing an amalgam of quicksilver and lead. This amalgam served as a reservoir of heat, which it took up from the fire below the double bottom, and gave forth at intervals to the water above it. There was no water in the boiler, in the ordinary sense of the term, but when steam was wanted to start the engine, a small quantity of water was injected by means of a hand pump, and after the engine was started there was pumped by it into the boiler, at each half revolution, as much water as would make the steam needed. This water was flashed on the top surface of the reservoir in which the amalgam was confined, and was entirely turned into steam, the object of the engineers in charge being to send in so much water as would just generate the steam, but so as not to leave any water in the boiler. The engines of the Vesta were made by Mr. Penn, for Mr. Howard, of the King and Queen Ironworks, Rotherhithe. Mr. Howard was, I fear, a considerable loser by his meritorious efforts to improve the steam engine.

There was used with this engine an almost unknown mode of obtaining fresh water for the boiler. Fresh water, it will be seen, was a necessity in this mode of evaporation. The presence of salt, or of any other impurity, when the whole of the water was flashed into steam, must have caused a deposit on the top of the amalgam chamber at each operation. Fresh water, therefore, was needed; the problem arose how to get it; and that problem was solved, not by the use of surface condensation, but by the employment of re-injection, that is to say, the water delivered from the hot well was passed into pipes external to the vessel; after traversing them, it came back into the injection tank sufficiently cooled to be used again. The boilers were worked by coke fires, urged by a fan blast in their ashpits, but I am not aware that this mode of firing was a needful part of the system.

I come now to the *Engines used for railways.* At the British Association meeting of 1831, the Manchester and Liverpool Railway had been opened only about a year. The Stockton and Darlington coal line, it is true, had carried passengers by steam power as early as 1825, but I think we may look upon the

Manchester and Liverpool as being the beginning of the passenger and mercantile railway system of the present day. At that time the locomotives weighed from eight to ten tons, and the speed was about 20 miles per hour, with a pressure of from 40 to 50 lbs. The rails were light; they were jointed in the chairs, which were generally carried on stone blocks, thus affording most excellent anvils for the battering to pieces of the ends of the rails—that is to say, for the destruction of the very parts where they were most vulnerable. The engines were not competent to draw heavy trains, and it was a common practice to have at the foot of an incline a shed containing a "bank engine," which ran out after the trains as they passed, and pushed them up to the top of the hill. Injectors were then unknown, and donkey pumps were unknown, and therefore, when it was necessary to fill up the boiler, if it had not been properly pumped up before the locomotive came to rest, it had to run about the line in order to work its feed-pumps. To get over this difficulty, it was occasionally the practice to insert into a line of rails, in a siding, a pair of wheels, with their tops level with that of the rails so that the engine wheels could run upon the rims. Then, the locomotive being fixed to prevent it from moving of the pair of wheels thus endways it was put into revolution, its driving wheels bearing, as already stated, upon the rims of the pair of wheels in the rails, and thus the engine worked its feed pumps without interfering (by its needless running up and down the line) with the traffic. It should have been stated that at this time there was no link motion, no practical expansion of the steam, and that even the reversal of the engine had to be effected by working the slides by hand gear, in the manner in use in marine engines. When the British Association originated, although the Manchester and Liverpool Railway had been opened for a year, there is no doubt that the 300 members who then came to this City found their way here by the slow process of the stage-coach, the loss of which we so much deplore in the summer and in fine weather, but the obligatory use of which we should so much regret in the miserable weather now prevailing in these islands.

In 1831, we know that railways are everywhere inserted. Steel rails, double the weight of the original iron ones, are used. Wooden sleepers have replaced the stone blocks, and they, in their turn, will probably give way to sleepers of steel. The joints are now made by means of fishplates, and the most vulnerable part of the rail, the end, is no longer laid on an anvil for a purpose of being smashed to pieces, but the ends of the rails are now almost always over a void, and thereby are not more affected by wear than is any other part of the rail. The speed is now from 50 to 60 miles an hour for passenger trains, while slow speed goods engines, weighing 45 tons, draw behind them coal trains of 800 tons. The injector is now commonly employed, and, by its aid, a careful driver of the engine of a stopping train can fill up his boiler while at rest at the stations. The link motion is in common use, to which, no doubt, is owing the very considerable economy with which the locomotive engine now works.

As regards the question of safety, it is a fact that, notwithstanding the increased speed, railway accidents are fewer than they were at the slow speed. It is also a fact that, if the whole population of London were to take a railway journey, there would be but one death arising out of it. Four millions of journeys for one death of a passenger from causes beyond his own control is, I believe, a state of security which rarely prevails elsewhere. As an instance, the street accidents in London alone cause between 200 and 300 deaths per annum. This safety in railway traveling is no doubt largely due to the block system, rendered possible by the electric telegraph; and also to the efficient interlocking of points and signals, which render it impossible now for a signalman to give an unsafe signal. He may give a wrong one, in the sense of inviting the wrong train to come in; but, although wrong in this sense, it would still be safe for that train to do so. If he can give a signal, that signal never invites to danger; before he can give it, every one of the signals, which ought to be "at danger," must be "at danger," and every "point" must have been previously set, so as to make the road right; then, again, we have the facing point-lock, which is a great source of safety.

Further, we have continuous brakes of various kinds, competent in practice to absorb three miles of speed in every second of time; that is to say, if a train was going 60 miles an hour, it can be pulled up in twenty seconds; or, if at the rate of 30 miles, in 10 seconds. With a train running at 50 miles an hour, it can be pulled up in from 15 to 20 seconds, and in a distance of from 180 to 240 yards. Moreover, in the event of the train separating into two or more sections, the brakes are automatically applied to each section, thereby bringing them to rest in a short time. Another cause of safety is undoubtedly the use of weldless tyres. I was fortunate enough to attend the British Association Meeting many years ago at Birmingham, and I then read a paper upon weldless tyres, in which I ventured to prophesy that, in ten years' time, there would not be a welded tyre made; that is one of the few prophecies that, being made before the event, have been fulfilled. I may perhaps be permitted to mention, that at the same time I laid before the Section plans and suggestions for the making of the cylindrical parts of boilers equally without seam, or even welding. This is rarely done at the present time, but I am sure that, in twenty years' time, such a thing as a longitudinal seam of rivets in a boiler will be unknown. There is no reason why the successive rings of boiler shells should not be made weldless, as tyres are now made weldless.

The next subject I intend to deal with is that of *Motors*. In 1831, we had the steam engine, the water wheel, the wind mill, horse power, manual power, and Stirling's hot-air engines. Gas engines, indeed, were proposed in 1824, but were not brought to the really practical stage. We had then tide mills; indeed, we have had them until quite lately, and it may be that some still exist; they were sources of economy in our fuel, and their abandonment is to me a matter of regret. I remember tide mills on the coast between Brighton and New Haven, another between Greenwich and Woolwich, another at Northfleet, and in many other places. Indeed, such mills were used pretty extensively; they were generally erected at the mouth of a stream, and in that way the river bed made the reservoir, and even when they were erected in other situations, those were of a kind suitable for the purpose, that is, low lying lands were selected, and were embanked to form reservoirs. In 1881, wind mills and water wheels are much the same, but the turbines are greatly improved, and by means of turbines we are enabled to make available the pressure derived from heads of water which formerly could not be used at all, or if used, involved the erection of enormous water wheels, such as those at Glasgow and in the Isle of Man, wheels of some eighty feet in diameter. But now, by means of a small turbine, an excellent effect is produced from high heads of water. The same effect is obtained from the water engines which our President has employed with such great success. In addition to these motors, we have the gas engine, which, within the last few years only, has become a really useful working and economical machine. With respect to horse-power motors, we have not only the old horse engines, but we have a new application (as it seems to me) of the work of the horse as a motor. I allude to those cases where the horse drawing a reaping or threshing machine, not only pulls it forward as he might pull a cart, but causes its machinery to revolve, so as to perform the desired kind of work. This species of horse engine, though known, was but little used in 1831. With respect to hot-air engines there have been many attempts to improve them, and some hot-air engines are working, and are working with considerable success; but the amount of power they develop in relation to their size is small, and I am inclined to doubt whether it can be much increased.

I now come to the subject of the *transmission of power*. I do not mean transmission in the ordinary sense by means of shafting, gearing, or belting, but I mean transmission over long distances. In 1831, we had for this purpose flat rods, as they were called, rods transmitting power from pumping engines for a considerable distance to the pits where the pumps were placed, and we had also the pneumatic, the exhaustion system—the invention of John Hague, a Yorkshireman, my old master, to whom I was apprenticed—which mode of transmission was then used to a very considerable extent. The recollection of it, I find,

however, has nearly died out, and I am glad to have this opportunity of reviving it. But in 1881, we have, for the transmission of power, first of all, quick moving ropes, and there is not, so far as I know, a better instance of this system than that at Schaffhausen. Any one who has ever, in recent years, gone a mile or two above the falls at Schaffhausen must have seen there—in a house, on the bank of the Rhine, opposite to that on which the town is situated—large turbines driven by the river, which is slightly damned up for the purpose. These work quick-going ropes, carried on pulleys, erected at intervals along the river bank, for the whole length of the town; and power is delivered from them to shafting below the streets, and from it into any house where it is required for manufacturing purposes. Then we have the compressed-air transmission of power, which is very largely used for underground engines, and for the working of rock drills in mines and tunnels. We have also compressed air in a portable form, and it is now employed with great success in driving tram cars. I had occasion last January to visit Nantes, where, for eighteen months, tramcars had been driven by compressed air, carried on the cars themselves, coupled with an extremely ingenious arrangement for overcoming the difficulties commonly attendant on the use of compressed air engines. This consists in the provision of a cylindrical vessel half filled with hot water and half with steam at a pressure of eighty pounds on the square inch. The compressed air, on its way from the reservoir to the engine, passes through the water and steam, becoming thereby heated and moistened, and in that way all the danger of forming ice in the cylinders was prevented, and the parts were susceptible of good lubrication. These cars, which start every ten minutes from each end, make a journey of $3\frac{3}{4}$ miles, and have proved to be a commercial and an engineering success. I believe, moreover, that they are capable of very considerable improvement. Then there is, although not much used, the transmitting of power by means of long steam pipes. There is also the transmission hydraulically. This may be carried out in an intermittent manner, so as to replace the reciprocating flat rods of old days; that is to say, if two pipes containing water are laid down, and if the pressure in those pipes at the one end be alternated, there will be produced an alternating and a reciprocative effect at the other, to give motion to pumps or other machinery. There is, also, that thoroughly well-known mode of transmission, hydraulically, for which the engineering world owes so much to our President. We have, by Sir William Armstrong's system, coupled with his accumulator, the means of transmitting hydraulically the power of a central motor to any place requiring it, and by the means of the principal accumulator, or if need be, by that aided by local accumulators, a comparatively small engine is enabled to meet very heavy demands made upon it for a short time. I think I am right in saying that, at the ordinary pressure which Sir William Armstrong uses in practice, viz., 700 lbs. to the square inch, one foot a second of motion along an inch pipe would deliver at the rate to produce one horse power. Therefore, a ten-inch pipe, with the water traveling at no greater pace than three feet in a second, would deliver 300 horse power. This 300 horse power would, no doubt, be somewhat reduced by the loss in the hydraulic engine, which would utilize the water. But the total energy received would be equivalent to producing 300 horse power. Such a transmission would be effected with an exceedingly small loss in friction in transit. I believe I am right in saying that a ten-inch pipe a mile long would not involve much more than about 14 or 15 lbs. differential pressure to propel the water through it at a rate of three feet in a second. If that be so, then, with 700 lbs. to the inch, the loss under such circumstances would be only two per cent. in transmission. There is no doubt that this transmission of power hydraulically has been of the greatest possible use. It has enabled work to be done which could not be done before. Enormous weights are raised with facility wherever required, as by the aid of power hydraulically transmitted, it is perfectly easy for one man to manage the heaviest cranes. Moreover, as I have said in other places, the system which we owe to Sir William Armstrong has gone far to elevate the human race, and

it has done so in this manner. So long as it is competent for a man to earn a living by mere unintelligent exercise of his muscles, he is very likely to do it. You may see in the old London docks the crane heads covered by structures that look like paddle boxes. If you go to them, there is, I am glad to say, nothing now to fill them up; but when the British Association first met, these paddle boxes covered large tread wheels, in which the men trod, so as to raise a weight. Now, although I know that in fact there is nothing more objectionable in a man turning a wheel by treading inside of it than there is if he turn it round by a winch handle, yet somehow it strikes one more as being merely the work of an animal, a turnspit, or a squirrel, or indeed as the task imposed on the criminal. But, nevertheless, in this way there was a large number of persons getting their living by the mere exercise of their muscles, but, as might be expected, a very poor living, derived as it was from unintelligent labor. That work is no longer possible, and is not so, for the powerful reason that it does not pay. Those persons, therefore, who would now have been thus occupied, are compelled to elevate themselves, and to become competent to earn their living in a manner which is more worthy of an intelligent human being. It is on these grounds that I say we owe very much the elevation of the working classes, especially of the class below the artisan, to this invention of our distinguished President. In addition to the modes of transmission I have already mentioned, there is the transmission of power by means of gas. I think that there is a very large future indeed for gas engines. I do not know whether this may be the place to state it, but I believe the way in which we shall utilize our fuel hereafter will, in all probability, not be by the way of the steam engine. Sir William Armstrong alluded to this probability in his address, and I entirely agree, if he will allow me to say so, that such a change in the production of power from fuel appears to be impending, if not in the immediate future, at all events in a time not very far remote; and however much the Mechanical Section of the British Association may to-day contemplate with regret—even the mere distant prospect of the steam engine being a thing of the past, I very much doubt whether those who meet here fifty years hence will then speak of it as anything more than a curiosity to be found in a museum. With respect to the transmission of power electrically, I won't venture to touch upon that; but will content myself by reminding you that while Sir William Armstrong did say that there were comparatively small streams which could be utilized, he did not inform you of that which he himself had done in this direction; let me say that Sir William Armstrong thus utilized a fall of water, situated about a mile from his house, to work a turbine, which drives a dynamo machine, generating electricity, for the illumination of the house. When I was last at Crag Side, that illumination was being effected by the arc light, but since then, as Sir William Armstrong has been good enough to write to me, he has replaced the arc light by the incandescent lamp (a form of electrical lighting far more applicable than the arc light to domestic purposes), and with the greatest possible success. Thus, in Sir William Armstrong's own case, a small stream is made to afford light in a dwelling a mile away. Certainly nothing could have seemed more improbable fifty years ago than that the light of a house should be derived from a fall of water, without the employment of any kind or description of fuel.

The next subject upon which I propose to touch, is that of the *Manufacture of iron and the steel.* In 1831, Nelson's hot blast specification had been published for 2½ years only. The Butterly Company had tried the hot blast for the first time in the November preceding the meeting of the British Association. The heating of the blast was coming very slowly into use, and the temperature attained when it was employed was only some 600 degrees. The ordinary blast furnace of those days was 35 to 40 feet high, and about 12 feet diameter at the boshes, and turned out about 60 tons a week. It used about 2½ tons of coal per ton of iron, and no attempt was made to utilize the waste gases, whether escaping in the form of gas or in the form of flame, the country being illuminated for miles around at night by these fires. The furnaces were also open at the hearth,

and continuous fire poured out along with the slag. In 1881, blast furnaces are from 90 ft. to 100 ft. high, and 25 ft. in diameter at the boshes; they turn out from 500 to 800 tons a week. The tops and also the hearths are closed, and the blasts—thanks to the use of Mr. E. A. Cowper's stoves—is at 1.200 degrees. The manufacture of iron has also now enlisted in its service the chemist as well as the engineer, and amongst those who have done much for the improvement of the blast furnaces, to no one is greater praise due than to Mr. Isaac Lowthian Bell, who has brought the manufacture of iron to the position of a highly scientific operation. In the production of wrought iron by the puddling process, and in the subsequent mill operations, there is no very considerable change, except in the magnitude of the machines employed, and in the greater rapidity with which they now run. In saying this, I am not forgetting the various "mechanical puddlers" which have been put to work, nor the attempts that have been made by the use of some of them to make wrought iron direct from the ore; but neither the "mechanical puddler" nor the "direct process" have yet come into general use; and I desire to be taken as speaking of that which is the ordinary process pursued at the present in puddled iron manufactures. In 1831, a few hundred weights was the limit of weight of a plate, while in 1881, there may readily be obtained, for boiler-making purposes, plates of at least four times the weight of those that were made in 1831. I may, perhaps, be allowed to say that there is an extremely interesting Blue Book of the year 1818, containing the report of a Parliamentary Committee which sat on boiler explosions, and I recommend any mechanical engineer who is interested in the history of the subject to read that book; he will find it there stated that in the North of England there were a species of engines called locomotives, the boilers of which were made of wrought iron beaten, not rolled, because the rolled plate was not considered fit; it was added that if made of beaten iron the boiler would last at least a year. In 1831, thirteen years later, the dimensions of rolled plates were, no doubt, raised; but few then would have supposed it possible there should be rolled such plates as are now produced for boiler purposes, and still fewer would have believed that in the year 1881 we should make, for warlike purposes, rolled plates 22 inches in thickness and 30 tons in weight. I have said there is very little alteration in the process of making wrought iron by puddling, and I do not think there is likely to be much further, if any, improvement in this process, because I believe that, with certain exceptions, the manufacture of iron by puddling is a doomed industry. I ventured to say, in a lecture I delivered at the Royal Institution three years ago on "The Future of Steel," that I believed puddled iron, except for the mere hand-wrought forge purposes of the country blacksmith, and for such like purposes, would soon become a thing of the past. Mr. Harrison, the engineer of the North-Eastern Railway, told me that, about eighteen months ago, the North-Eastern Railway applied for tenders for rails in any quantities between 2,000 and 10,000 tons, and they issued alternative specifications for iron and for steel. They received about ten tenders. Some did not care to tender for iron at all; but when they did tender alternatively, the price quoted for the iron was greater than that for the steel. I have no doubt whatever, that in a short time it will be practically impossible to procure iron made by the puddling process, of dimensions fit for many of the purposes for which a few years ago it alone was used. With respect to steel: In 1831, the process in use was that of cementation, producing blistered steel, which was either piled and welded to make sheer steel, or was broken into small pieces, melted in pots, and run into an ingot weighing only some 50 lbs. or 60 lbs. At that time, steel was dealt in by the pound; nobody thought of steel in tons. In 1881, we are all aware that, by Sir Henry Bessemer's well-known discovery, carried out by him with such persistent vigor, cast iron is, by the blowing process, converted into steel, and that, by Dr. Siemen's equally well-known process (now that, owing to his invention of the regenerative furnace, it is possible to obtain the necessary high temperature), steel is made upon the open hearth. We are, moreover, aware that, by both of these processes, steel is produced in quantities

of many tons at a single operation, with the result that, as instanced in the case of the North-Eastern rails, steel is a cheaper material than the wrought iron made by the puddling process. One cannot pass away from the steel manufacture without alluding to Sir Joseph Whitworth's process of putting a pressure on the steel while in a tried state. By this means, the cavities which are frequently to be found in the ingot of a large size, are, while the steel is fluid, rendered considerably smaller, and the steel is thereby rendered much more sound. In conclusion of my observations on the subject of iron and steel manufacture, I wish to call attention to the invention of Messrs. Thomas and Gilchrist, by which ores of iron, containing impurities that unfitted them to be used in the manufacture of steel, are now freed from these impurities, and are thus brought into use for steel-making purposes.

Bridges.—In the year 1831, bridges of cast iron existed; but no attempt had been made to employ wrought iron in girder bridges, although Telford had employed it in the Menai Suspension Bridge; but in 1881, the introduction of railways, and the improvement in iron manufactures, have demanded, and have rendered possible the execution of such bridges as the tubular one, spanning the Menai Straits, in span of 400 feet, and the Saltash, over the Tamar, with spans of 435 feet; while recent great improvements in the manufacture of steel have rendered possible the contemplated construction of the Forth Bridge, where there are to be spans of 1,700 feet, or one-third of a mile in length. Mr. Barlow, one of the engineers of this bridge, has told me that there will be used upwards of 2,000 more tons of material in the Forth Bridge, to resist the wind pressure, than would have been needed if no wind had to be taken into account, and if the question of the simple weight to be carried had alone to be considered. With respect to the foundation of bridges, that ingenious man, Lord Cochrane, patented a mode of sinking foundations, even before the first meeting of the British Association, viz., as far back, I believe, as 1825 or 1826; and the improvements which he then invented are almost universally in use in bridge construction at the present day. Cylinders sunk by the aid of compressed air, air-locks to obtain access to the cylinder, and in fact every means that I know of as having been used in the modern sinking of cylinder foundations, were described by Lord Cochrane (afterwards Earl of Dundonald) in that specification.

The next subject I propose to touch on, is that of *Machine Tools.* In 1831, the mention of lathes, drilling machines, and screwing machines, brings me very nearly to the end of the list of the machine tools used by turners and fitters, and at that time many lathes were without slide rests. The boilermaker had then his punching press and shearing machine; the smith, leaving on one side his forges and their bellows, had nothing but hand tools, and the limit of these was a huge hammer, with two handles, requiring two men to work it. In anchor manufacture, it is true, a mechanical drop-hammer, known as Hercules, was employed, while in iron works, the Helve and the Tilt hammer were in use. For ordinary smith's work, however, there were, as has been said, practically no machine tools at all.

This paucity or absence in some trades, as we have seen, of machine tools, involved the need of very considerable skill on the part of the workman. It required the smith to be a man not only of great muscular power, but to be possessed of an accurate eye and a correct judgment, in order to produce the forgings which were demanded of him, and to make the sound work that was needed, especially when that soundness was required in shafts, and in other pieces which, in those days, were looked upon as of magnitude; which, indeed, they were, relatively to the tools which could be brought to operate upon them. The boiler maker in his work had to trust almost entirely to the eye for correctness of form and for regularity of punching, while all parts of engines and machines which could not be dealt with in the lathe, in the drilling, or in the screwing machine, had to be prepared by the use of the chisel and the file.

At the present day, the turning and fitting shops are furnished, not only with the side lathe, self-acting in both directions, and screw-cutting, the

drilling machine and the screwing machine, but with planing machines competent to plane horizontally, vertically, or at an angle; shaping machines, rapidly reciprocating, and dealing with almost any form of work; nut-shaping machines, slot-drilling machines, and slotting machines, while the drills have become multiple and radial; and the accuracy of the work is ensured by testing on large surface plates, and by the employment of Whitworth internal and external standard guages.

The boiler-maker's tools now comprise the steam, compressed air, hydraulic or other mechanical riveter, rolls for the bending of plates while cold into the needed cylindrical or conical forms, multiple drills for the drilling of rivet holes, planing machines to plane the edges of the plates, ingenious apparatus for flanging them, thereby dispensing with one row of rivets out of two, and roller expanders for expanding the tubes in locomotive and in marine boilers; while the punching press, where still used, is improved so as to make the holes for seams of rivets in a perfect line, and with absolute accuracy of pitch.

With respect to the smith's shop, all large pieces of work are now manipulated under heavy Nasmyth or other steam hammers; while smaller pieces of work are commonly prepared either in forging machines or under rapidly moving hammers, and when needed in sufficient numbers are made in dies. And applicable to all the three industries of the fitting shop, the boiler shop, and the smith's shop, and also to that other industry carried on in the foundry, are the traveling and swing cranes, commonly worked by shafting, or by quick-moving ropes for the travelers, and by hydraulic power or by steam engines for the swing cranes. It may safely be said that, without the aid of these implements it would be impossible to handle the weights that are met with in machinery of the present day.

I now come to one class of machine which, humble and small as it is, has probably had a greater effect upon industry and upon domestic life than almost any other. I mean the *Sewing Machine.* In 1831, there was no means of making a seam except by the laborious process of the hand needle. In 1846, Eldred Walker patented a machine for passing the basting thread through the gores of umbrellas, a machine that was very ingenious and very simple, but was utterly unlike the present sewing machine, with its eye-pointed needle, using sometimes two threads (the second being put in by a shuttle or by another needle), and making stitches at twenty fold the rapidity with which the most expert needle-woman could work. By means of the sewing machine not only are all textile fabrics operated upon, but even the thickest leather is dealt with, and as a *tour de force*, but as a matter of fact, sheet-iron plates themselves have been pierced, and have been united by a seam no boiler-maker ever contemplated, the piercing and the seam being produced by a Blake sewing machine. I believe all in this Section will agree that the use of the sewing machine has been unattended by loss to those who earn their living by the needle; in fact, it would not be too much to say that there has been a positive improvement in their wages.

The next matter I have to touch upon is *Agricultural machinery.* In 1831, we had threshing machines and double plows, and even multiple plows had been proposed, tried and abandoned. Reaping machines had been experimented with and abandoned; sowing machines were in use, but not many of them; clod crushers and horse rakes were also in use; but as a fact plowing was done by horse power with a single furrow at a time; mowing and reaping were done by the scythe or the sickle, sheaves were bound by hand, hay was tedded by hand rakes, while all materials and produce were moved about in carts and in wagons drawn by horses. At the present time we have multiple plows, making five or six furrows at a time, these and cultivators, also driven by steam, commonly from two engines on the head lands, the plow being in between, and worked by a rope from each engine, or if by one engine, a capstan on the other head land, with a return rope working the plow backwards and forwards; or by what is known as the round-about system, where the engine is fixed and the rope carried round about the field; or else plows and cultivators are worked by ropes from two capstans placed on the

two head lands, and driven by means of a quick-going rope, actuated by an engine, the position of which is not changed. And then we have reaping machines, driven at present by horses; but how long it will be before the energy residing in a battery, or that in the reservoir of compressed air, will supersede horse power to drive the reaping machine, I don't know, but I don't suppose it will be very long. The mowing and reaping machines not only cut the crop and distribute it in swathes, or, in the case of the reaping machines, in bundles, but now, in the instance of these latter machines, are competent to bind it into sheaves. In lieu of hand tedding, hay-making machines are employed, tossing the grass into the air, so as to thoroughly aerate it, taking advantage of every brief interval of fine weather; and seed and manure are distributed by machines with unfailing accuracy. The soil is drained by the aid of properly constructed plows for preparing the trenches; roots are steamed and sliced as food for cattle; and the threshing machine no longer merely beats out the grain, but it screens it, separates it, and elevates the straw, so as to mechanically build it up into a stack. I do not know a better class of machine than the agricultural portable engine. Every part of it is perfectly proportioned and made; it is usually of the locomotive type, and the economy of fuel in its use is extremely great. I cannot help thinking that the improvement in this respect which has taken place in these engines, and the improvement of agricultural machinery generally, is very largely due to the Royal Agricultural Society, one of the most enterprising bodies in England.

I now come to the very last subject I propose to speak upon, and that is *Printing machinery*, and especially as applied to the printing of newspapers. In 1831, we had the steam press sending out a few hundred copies in an hour, and doing that upon detached sheets, and thus many hours were required for an edition of some thousands. The only way of expediting the matter would have been to have recomposed the paper, involving, however, double labor to the compositors, and a double chance of error. At the present day, we have, by the Walter press, the paper printed on a continuous sheet at a rate per hour at least three times as great as that of the presses of 1831, and, by the aid of *papier mache* moulds, within five minutes from the starting of the first press, a second press can be got to work from the stereotype plates, and a third one in the next five minutes; and thus the wisdom of our senators, which has been delivered as late as three o'clock in the morning, is able to be transmitted by the newspaper train leaving Euston at 5:15 A. M.

This is the last matter with which I shall trouble the Section. I have purposely omitted telegraphy; I have purposely omitted artillery, textile fabrics, and the milling and preparation of grain. These and other matters I have omitted for several reasons. Some I have omitted because I was incompetent to speak upon them, others because of the want of time, and others because they more properly belong to Section A.

I hope, sir, although your address, dealing with the future, was undoubtedly the right address for a President to deliver, and although it is equally right that we should not content ourselves with merely looking back in a "rest-and-be-thankful" spirit at the various progress which this paper records, it may nevertheless be thought well that there should have been brought before the Section, in however cursory a manner, some notice of mechanical development during the past fifty years.

DR. PHIPSON recently communicated to the Académie des Sciences, Paris, a note expressing his belief that commercial zinc generally contains some small proportion of another metallic element, for which the author proposes the term *actinium* to characterize its curious actinic phenomena. Precipitating the metal with sulphide of barium, washing, drying, and calcining, a white sulphide of zinc is obtained, which, under the influence of the direct solar rays, changes in about thirty minutes to a slate color, but returns to the original white if kept again in darkness, but with free access of air. The phenomenon does not occur, the *Chemist and Druggist* says, however, if the solar rays pass through glass.

THE PREVENTION OF WASTE OF WATER.*

By THOMAS STEWART, Stud. Inst. C.E.

From Selected Papers of the Institution of Civil Engineers.

THE prevention of the waste of water has of late years received considerable attention from engineers in charge of the supply and distribution of water in towns. Various circumstances have led to this, the chief being that new works which had been expected to afford ample supplies to the towns for whose use they had been designed have proved insufficient; and it has become necessary to consider what steps should be taken to meet the emergency. One way is to give an intermittent supply; another, to extend the works. The former method is gradually going out of use on account of the sanitary evils which accompany it. The latter is not always practicable, as the resources may be exhausted; or, if water be available, the cost of introducing it may be excessive.

In order to avoid the expense of new works on the one hand, and the evils of an intermittent supply on the other, attention has been directed to the causes of the increased consumption, and while it has been found that the quantity of water legitimately used has been slowly on the increase, it has also been found that the greater part of the increase in the consumption is due to waste from defective pipes and fittings belonging to the consumers.

Waste throughout this paper is applied to water which flows from defects in the service pipes and fittings, and does not include the waste due to extravagance in the use of water.

In order to give corporations and water companies some control over the consumers' pipes and fittings, several general Acts of Parliament have been passed. These have been of use when the prevention of waste was not urgent; but when strong action has been required, special Acts have been found necessary. Under such Acts numerous towns have succeeded in reducing the waste to so great an extent, that their insufficient supplies have been converted into abundant ones, without interfering with the quantity of water required.

In carrying out operations for the prevention of waste, much information has been obtained regarding the sources of waste and its extent. In this paper the author describes the sources of waste, the regulations as to apparatus for preventing it; methods employed for the detection and prevention of waste, and the results obtained.

I.—SOURCES OF WASTE.

These may be divided into three classes:

(1) Defective water fittings.
(2) Defective service pipes.
(3) Defective distributing pipes.

(1.) *Defective water fittings.*—These have always been the most fruitful sources of waste, and being chiefly inside houses and often in out-of-the-way corners, they are not readily seen by water inspectors. The occupants seldom trouble themselves about waste so long as water does not squirt about the house or annoy them by its noise. Previous to engineers prescribing in detail the uses and kinds of water fittings to be employed, plumbers were in the habit of putting in very inferior articles, cheapness in their estimation being of more consequence than first-class work. Except in the better-regulated water works, this practice was general throughout the country until within about the last twenty-five years. However, the prescribing of the kinds of fittings, and testing and stamping them, are making a great improvement in this matter; but where special measures have been resorted to of late years for the prevention of waste, these old and imperfect fittings have been a continual source of annoyance, and except in rare cases, where there are powers for compelling their removal, have retarded the operations. These defective fittings consisted chiefly of ground cocks and water-closets supplied direct from the main by taps. In three or four months after being put on, the ground cocks were found wasting water, and at any time

* This communication was read and discussed at a meeting of the students on the 8th of April, 1881, and has been awarded a Miller prize.

the taps to the water-closets allowed a continuous flow. Before 1860 these classes of water fittings had ceased to be used in well-regulated water works. In Glasgow they were prohibited shortly after the introduction of water from Loch Katrine in 1860. On account of the consumption rising at an extraordinary rate during the summer of that year, Mr. Bateman, Past President Inst. C.E, drew the attention of the corporation to the matter. Mr. Gale, M. Inst., C.E., engineer to the Water-works Commissioners, made a special inspection of the fittings in several parts of the town, and he found that the greatest waste was from common ground ball-cocks in cisterns; fifty-three of these were found wasting 12,500 gallons per day, and ninety-nine common ground stop cocks were wasting 11,700 gallons. At this time three-fourths of the total number of cocks in use were of the common ground kind.

The result of Mr. Gale's investigations led to the following rules:

(1) "That no common ground cock be allowed for the future to be supplied direct from the main service pipe or from a cistern, except it be on the same floor as the tap, and that screw-down cocks only be used for this purpose.

(2) "That no water closet be allowed to be supplied direct from the main service pipe by any kind of tap, but be supplied from cisterns."

By enforcing these rules, and by the aid of a system of rigid house-to-house inspection, a saving of 5,000,000 gallons per day, or 11 gallons per head per day, was effected, and this continued until the commissioners relaxed the regulations.

In 1864, in order to ascertain how many of the existing fittings complied with the requirements of the above rules, an examination of the whole water fittings was made. The kinds which did not comply amounted to 41 per cent. of the whole, and during the examination every eighth tap was found wasting water.

The Water Company of Norwich, working under their special Act of Parliament of 1859, reduced the consumption from about 40 gallons to less than 14½ gallons per head per day. Mr. Ayris, M. Inst. C. E., the manager, attributed one-half of this saving to the introduction of screw-down cocks, and the other half to abolishing cocks to water closets and ground ball cocks to cisterns.

Newcastle affords another example of great saving by adopting proper taps and water closets. Mr. Main, the manager, in his evidence on the East London Water works Bill, 1867, states that on account of the flagrant waste from badly constructed taps and water closets, a rigid inspection was instituted, and the proprietors were called upon to make the necessary repairs and alterations. In one district after double-valve cisterns had been put into every house, the consumption fell from 32½ to 16½ gallons per head per day.

(2) *Defective service pipes.*—These are not so numerous as defective fittings in proportion to the number of persons supplied; but while the waste from them is not so great, the possibilities of discovering it are fewer on account of the pipes being in great part underground. Except when a service pipe bursts inside a house, thereby causing damage, the waste from this source is apt to be continuous, unless there is a want of pressure in the houses, or the water shows at the surface. As an instance, in Glasgow, during 1876, of 10,825 complaints of want, or information of waste, of water received, 3,294 were found to be caused by burst lead service pipes.

Service pipes are usually of lead, and may be defective by being too light for the pressure, by bad material being used in their construction, or by inferior workmanship. The lightness and bad material may be detected by inspecting the pipes before they are covered up, and in some cases so may the inferior workmanship; but owing to splits occurring in the inside of the pipe during manufacture, and not appearing on the outside, the difficulty of ensuring the absence of defects of this sort is great.

When the pipes are of iron, it is usually stipulated that they shall be subjected to a certain pressure before being used, and the laying of them is superintended by an officer from the water works. In some towns, such as Rochdale, Carlisle, and others, it is the practice for the corporation to lay the service pipes up to or through the boundary wall, while in other towns the proprietors' plumbers lay the service pipes to the mains.

It frequently happens that on a new supply being introduced to towns, the

pressure is much increased, and this causes the service pipes, which may have been sufficiently strong for the old state of things, to give way. Norwich, Dublin,* and Glasgow afford instances of an increased supply acting injuriously on the old service pipes. Unless special powers have been secured for compelling the removal of such service pipes, the reduction of waste is a slow process.

(3) *Defective distributing pipes.*—The remarks made in reference to defective service pipes are in great part applicable to distributing pipes. When newly laid they are usually tight, and the quality of the pipes is insured by the water companies specifying the proportions of metal to be used, and superintending the making and testing of them. They become defective by local subsidence of the pipe-track, causing blown joints and splits in the pipe, and by defects not always capable of being explained. Defects in them are discovered by the water rising to the surface, or, when not rising and the waste is great, by want of pressure in the locality. Waste from this source has been known to continue for years without showing any signs on the surface or causing a defective supply, and Mr. Deacon, M. Inst., C. E.,† states that he has seen the edges of the cracks in the pipes worn smooth by the continual action of the water. In Glasgow two defects were recently discovered by the falling in of the surface of the street: the water in each case had made its way into the sewer, and in one instance had formed a tunnel large enough for a man to walk from the sewer to the main. In the other instance five cart-loads of material were required to fill up the cavity. The defects were on 3-inch and 4-inch pipes respectively. There were no reliable data to show how long the leaks had been in existence.

(1) *Regulations for securing proper service pipes and fittings.*—For the purpose of securing proper service pipes and water fittings, engineers of water works have been for some time in the habit of prescribing the classes and qualities to be adopted. In order the better to secure these ends, some towns, including Blackburn, Norwich, Yarmouth, Rochdale and Preston, do the greater part of the work themselves; others issue specifications, and make contracts with brassfounders for the supply of the necessary fittings; while others keep samples, to which all apparatus must conform, and, in addition, most of them test and stamp approved fittings. Manchester, Liverpool, Bolton, Glasgow and Dublin test and stamp. The system was first introduced at Manchester. There are modifications in the details of the system as carried out in the various towns, but the following regulations are common to most: Prescribing the kinds and qualities of the fittings to be used; keeping samples, to which all fittings must conform; weighing and gauging certain parts of the fittings; subjecting cocks to a pressure about three times as great as that which they will have to stand when in use; examining water-closet cisterns to ascertain that they give a flush of 1½ gallons or 2 gallons within three or four seconds; stamping approved apparatus; charging a small fee for the work.

These measures ensure that water fittings of good quality are used, and they have led to cocks constructed on screw-down principles being the rule. Water-closet cisterns have now to be made so that not more than 2 gallons of water can be used at a single flush, thus abolishing the evil of having the water running for a certain time by tying up the handle.

(2) *Regulations regarding water fittings in Glasgow.*—By the Glasgow Corporation Water works Act, 1856, the Water works Commissioners have powers to make by-laws for the prevention of waste and misuse of the water, and to impose penalties for breaches of such by-laws. The Act of 1859 provides that all apparatus in use, or proposed to be used, shall be subject to the approval of the engineer to the commissioners.

The regulations made in 1860 have been gradually amended, the most important additions being the recommendation of double-valve cisterns to water closets in 1868, and in 1873 the insisting on cisterns giving no more than 2 gallons at a flush. In October, 1875, certain classes of fittings were proscribed because they were not of the waste-preventing kind. A list of these is given in Appendix I. When found wasting water twice in three months, they have to be removed, and they are not allowed to be fitted up

* *Vide* Minutes of Proceedings Inst. C. E., vol. xxxviii., p. 48.

† *Vide* Minutes of Proceedings Inst. C. E., vol. xlii., p. 158.

in new premises. In 1876 it was resolved that overflow pipes should be brought outside the building, or made to discharge inside, so that the water could not escape without being seen. In April, 1877, lead service pipes under the regulation weight were proscribed. At present, when found wasting water twice in six months, they must be removed, so far as they are underground or in unoccupied cellars. In 1877 the system of testing and stamping was introduced. With some modifications in detail it is the same as carried out in other towns, Cocks to be supplied direct from the main are tested to a pressure of 300 lbs., and ball-cocks for cisterns to a pressure of 150 lbs. per square inch. Lavatory and other fittings, supplied off cisterns, are tested to a pressure of 25 lbs. The fittings which fulfill all the requirements are stamped.

The following table shows the improvement effected in the manufacture of the fittings since the introduction of the system of testing and stamping:

Year.	Number Examined.	Number Rejected.	Per cent. Rejected.
1877	4,369	640	14.60
1878	26,931	1,710	6.30
1879	24,300	989	4.07
1880	27,517	1,081	3.92

The regulations specify the service pipes to be of lead, and, unless otherwise specially agreed upon, no other kinds are permitted. The following are the weights per yard; ½-inch, 7 lbs.; ¾-inch, 10 lbs.; 1-inch, 14 lbs.; 1¼-inch, 18 lbs.; 1½-inch, 24 lbs.

When the service pipes are allowed to be of cast iron, they must be of the following dimensions and weights:

Diameter of Pipe.	Thickness of Pipe.	Depth of Socket.	Length of Pipe, exclusive of Socket.	Mean Weight of each Pipe.		
Inches.	Inch.	Inches.	Feet.	Cwt.	qrs.	lbs.
4	3/8	3	9	1	1	25
3	3/8	3	9	1	0	17
2	3/8	3	6	0	2	4

The greatest pressure to which these pipes are likely to be subjected under ordinary circumstances is about 100 lbs. per square inch, but the pressure which causes most pipes to burst, viz., that due to shutting taps, is not so easily ascertained.

(3) *Work in connection with supply to premises.*—No pipe or fitting is allowed to be covered up until an inspector has ascertained that it fulfills all the required conditions. Service pipes must be provided with stop-cocks about 2 feet from where they leave the distributing pipe, and must be laid 2 feet 6 inches below the surface; where exposed, they must be properly protected against frost.

Where cisterns have to be provided for the ordinary supply, a ball-cock is put on and so adjusted as to shut when the water is 2 inches from the top of the overflow pipe.

Screw-down cocks only are used when supplied direct from the main, or from a cistern on any other than the same floor. Common ground cocks and ground cocks with stuffing boxes may be used where the supply is from a cistern on the same floor, or, in "self-contained" houses, in the floor above. Water-closets and urinals are provided with cisterns having waste-preventing apparatus, so constructed that in water-closets not more than 2 gallons can be used at a single flush, and in urinals not more than ½ a gallon. "Waste not," or self-closing cocks, may be used for supplying the latter. Wells in courts and taps on stairs must be self-closing.

II.—Methods for Detecting and Preventing Waste.

(1) *House-to-house inspection*, the oldest and most common method for detecting waste, is in use in most of the larger towns throughout the kingdom, in some of which it is the only method employed; elsewhere it is used in conjunction with meters and other appliances. As carried out in most towns it consists in dividing the town into districts and appointing an inspector to each district, whose duties are to regularly visit the houses, inspect the water fittings in each house, and take a note of those wasting water. Thereafter a notice is left with the tenant, or one is sent to the owner, informing him of the defective state of the fitting, and calling upon him to make the repairs within a certain number of days. Some

water companies and corporations repair the washers and other small articles free of charge, but in these cases the water fittings are of one maker's patterns. The inspector examines the defective fittings a second time within a certain number of days. If the repairs are not executed the water is shut off, or the inspector reports the matter to the engineer, who then orders his plumbers to execute the repairs, and charges the cost to the owner. The practice of making the repairs and charging the cost to the owner is not largely followed, as disputes continually arise, either regarding the correctness of the charge or the proper person to be charged.

There can be no doubt that to shut off the water at the stop-cock is the most effectual appeal to the parties liable. The practice at first sight appears somewhat arbitrary, as there are at times more than eight tenants to one stop-cock, seven of whom may be ignorant of anything being wrong. This may be partly remedied, if the repairs are delayed too long, by beating up the pipe leading to the offending tap, or by locking up the tap itself, assuming, of course, that either of these courses is practicable.

In Glasgow the practice is for the inspector, during his first inspection, to enter in a book a description of the fittings found wasting, and to take a note of those in good repair. On the evening of the same day a notice is sent to the owner or factor, as the case may be, calling upon him to effect the repairs within two days. The inspector makes his second inspection within six days after. If the repairs are not made, the bad tap is locked up, or, if this cannot be done, the water is shut off at the stop-cock. The pipe leading to the tap, &c., might be beaten up, and thus save the other tenants annoyance, but the proceeding causes damage to woodwork and plaster. This is done, and the water restored to the other tenants, if the repairs are delayed beyond a reasonable time. When much water is running to waste the inspector shuts it off during his first inspection. Special reports are made on lead pipes found burst twice in six months, and on the proscribed fittings enumerated in Appendix I.

That the system of house-to-house inspection is valuable in preventing waste is proved by the numerous instances in which, when combined with the removal of bad fittings, the consumption has been reduced by one half. Manchester, Cambridge, and Newcastle, afford well-known instances. In Glasgow, in 1873, an addition of four inspectors was made to the staff, raising the number to twelve. In that year the average consumption of water per day was 800,000 gallons less than during the previous year. Part of this decrease was no doubt due to the increased number of inspectors.

(2) *District meter system.*—As the system of house-to-house inspection does not localize the sources of waste, all the districts receive the same attention, and as experience has proved that the waste varies much in different districts, attention is thereby thrown away. To obviate this, and to enable the worst districts to receive the most attention, meters have been put on the distributing pipes supplying these. By registering the quantity of water passing they enable those in charge to ascertain whether the consumption is above or below the average—assuming that the population in each district is known.

The meters used for this purpose may be divided into two classes, namely, ordinary meters, or such as register by an index the total quantity of water passed in a certain time; and automatic registering meters, which by means of diagrams show the rate of consumption at any hour or part of an hour.

Ordinary meters.—Of the numerous meters belonging to this class, Kennedy's piston meter and Siemens' turbine meter are the best known. Neither of these is intended for detecting waste; but notwithstanding, both of them have been, and are still, used to a considerable extent. As neither of these meters of itself registers the flow of water at a particular time, it is necessary, should this be wanted, to station an observer by the meter for the purpose of reading the index at the required intervals. It is an important peculiarity of the district meter system that the effect of shutting a pipe or tap through which water is passing shall be shown by the meter. This ordinary meters fail to do in a sufficiently clear manner, unless the waste has been excessive. However, they give a more reliable account of the total quantity passed in a certain number of hours than the meters which register by diagram.

In Newcastle several districts were put under the control of ordinary meters; in four of these at the starting of the meters the consumption of water was at the rate of 55, 60, 61, and 62 gallons per head per day; after the repairs and renewal of fittings and service pipes had been carried out, the consumption in the four districts was at the rate of 34, 39, 25, and 26 gallons respectively.*

In Liverpool in 1872,† fourteen districts, containing 31,080 persons, were put under the control of as many ordinary piston meters. The locality of the waste was determined by "sounding" the stop-cocks at night, and next day inspecting the premises where water had been found passing. After several of the day and night inspections had been made in each of the districts, the consumption, which before the starting of the meters had been, under nine hours (intermittent) service, 19.5 gallons, and under constant service, 33.5 gallons was reduced, under constant service, to about 12 gallons. These quantities are exclusive of water used for trade purposes.

In Glasgow, about the same time, similar experiments had been made by placing three of Siemens' meters on as many districts; the first district contained 738 persons, the second 2,299, and the third 1,391. The effect of the repairs was to reduce the total consumption in the first district from 60 to 38 gallons per head per day; in the second from 45 to 20; and in the third from 77½ to 50 gallons.

The sources of waste were ascertained to be burst service pipes, water-closets supplied by various kinds of taps direct off the main, and common ground cocks. The distributing pipes were tight in all the districts.

Automatic meters registering by diagrams.—These are now being largely employed for the purpose of checking waste by localizing its sources. Some experiments have been made with Kennedy's and with Tylor's meters, which in addition to the recording index have been provided with diagrams, but their use has not become general. The one in ordinary use is the waste-water meter, invented by Mr. Deacon, M. Inst. C.E., engineer of the Liverpool waterworks, and first applied by him to districts in that town.‡

In October, 1873, the first meter was fixed in Liverpool: by the 10th of April, 1875, one hundred and twenty meters were fixed, having under control 306,912 persons; of these, districts containing 117,425 persons had received most attention, and the consumption, which under constant service had been 32.12 gallons, was reduced to 15.9 gallons per head per day. In 1865 intermittent service had to be given on account of the increased consumption; but in 1875 the result of the operations connected with the meter system enabled the constant supply to be restored to nearly the whole area of supply. On the 26th of January, 1881, two hundred and five meters were in operation, having under control 705,146 persons, and the average consumption before the frost had set in was 21½ gallons per head per day, including supplies for all purposes; deducting the water sold for trade purposes the rate was 13¼ gallons.

The waste-water meter was applied to a large district in Glasgow in April, 1876, and afterwards the system was extended to other districts in various parts of the town. The method followed for reducing the waste differs considerably in details from that pursued in Liverpool, partly because the arrangement of the distributing pipes and dwelling houses is different, and partly because the conditions of supply are not comparable. The following description may therefore be permissible,

While the experiments with the three Siemens' meters were being made, a fourth district containing 667 persons was put under the control of a waste-water meter. After the repairs which followed the first night inspection had been effected, the consumption of water fell from 65¼ to 41 gallons per head per day, and the rate between 1 A. M. and 5 A. M., from 57 to 31 gallons per head. On the strength of these results, Mr. Gale recommended a large experimental district to be proceeded with, and the waste-water meter to be used.

Districts.— The experimental district selected contains 14,972 persons. It was divided into nine sub-districts, on each of which a meter was placed. A year after the meters had been put in working order, the results were, by Mr. Gale, considered sufficient to warrant the extension of the system to nine additional districts. The last meter was fixed in August, 1878.

* *Vide* Evidence on East London Water Works Bills, 1867.

† *Vide* Min. of Proceedings Inst. C.E., vol. xlii., p. 140.

‡ *Ibid.*, vol. xlii., pp. 143–160.

The additional districts were divided into forty-one sub-districts, and the piping in forty of them was put under the control of waste-water meters; the piping in one sub-district was put under the control of a Kennedy's piston meter, provided with a self-registering apparatus and diagram, Figs. 1, 2, and 3.

In selecting the districts, every endeavor was made to include as many varieties of house property as possible, and to exclude the business and manufacturing parts of the town. The property controlled by the meters embraces various classes of "tenement" houses; houses in courts, and "self-contained" houses. The rental varies from £300, to less than £2 per annum. Some particulars regarding the class of property in three of these districts are given in the following Table:—

Number of stopcocks.	Number of occupants at night.	Class of property.	Gallons per head per day.			
			At starting of meters.		After three first inspections.	
			Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.
79	2,971	Good tenement houses £12 to £24 rental, with a few inferior tenement houses, £3 to £10 rental. About fifty shops about £30 to £100 rental.....	60.0	42.5	34.0	16.4
98	731	High-class property, chiefly self-contained houses, £80 to £300 rental, with a few tenement houses, £40 to £60 rental. No shops.....	146.4	152 7	60.0	48.2
42	1,562	Old property, chiefly low-class tenement houses, about £2 to £8 rental, with a few better houses about £8 to £16 rental. A few inferior shops, £6 to £22 rental.....	14.3	7.4	13.3	4.8

The proceedings carried out, when it was proposed to put a district under the meter system, were as follows:—

1. A sketch was prepared of the main piping as it existed.

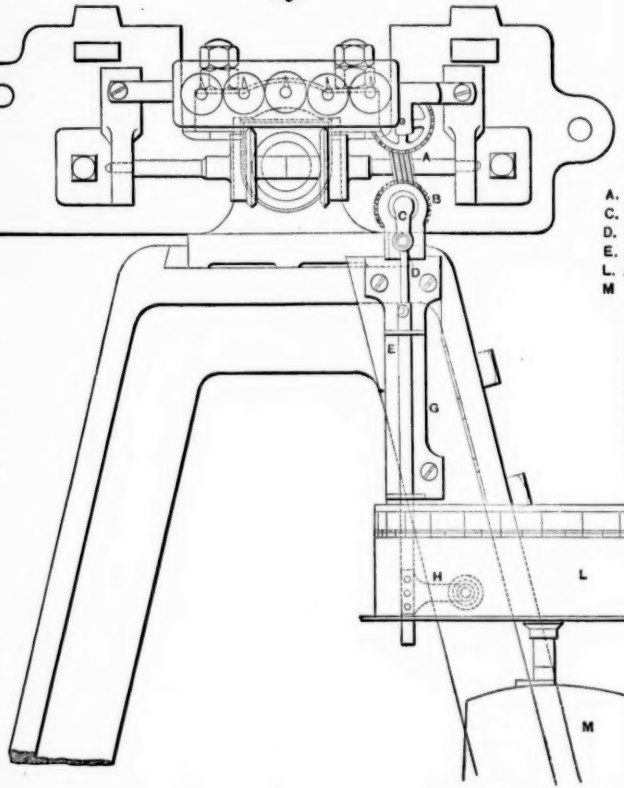
2. The approximate number of families was ascertained in each district proposed to be included.

3. The district was divided into sub-districts containing such a population that, during the hours of greatest consumption of water, the limits of the meter diagram should not be exceeded.

4. Each district was arranged to include a population as nearly equal as possible. This was not carried very far, as it would have necessitated the laying of additional piping. The piping is in short lengths, except in sub-district II. 5, where it is in moderately long lengths. A 4-inch pipe is seldom laid within the city of a longer length than 150 yards, and supplies from 50 to one hundred and fifty families only. This arrangement is for a plentiful supply of water in case of fire. Had the piping been altered so that the populations in the meter districts should have been equal, the efficiency of the fire cocks would, in most of the districts, have been seriously interfered with, unless considerable lengths of additional piping had been put down to make new connections to the principal mains. The efficiency of the fire cocks was maintained, and the isolation of the sub-districts secured by connecting some of the distributing pipes to each other, and disconnecting others without strict regard to equalizing the populations.

After the alterations in the piping had

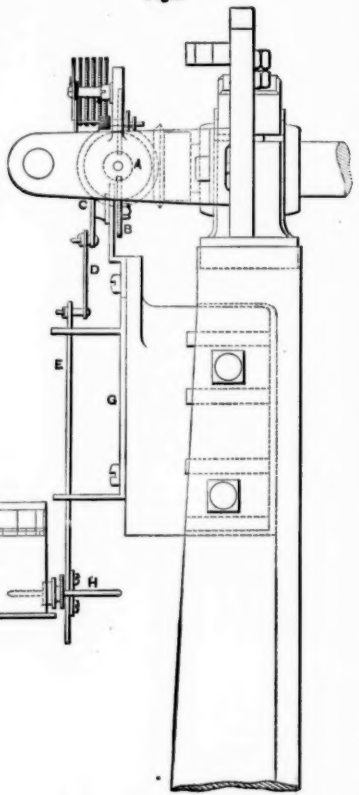
Fig.1



A. *Worm shaft driving Index wheels and wheel* B.
C. *Crank attached to shaft of* B.
D. *Connecting rod.*
E. *Rod moving in guide* G *and carrying pencil* H.
L. *Drum revolving once in 24 hours carrying diagram.*
M *Clock for driving drum.*

The worm-wheel (B) *carrying the crank* (C) *on its shaft, in making a complete revolution, causes the rod* (E) *to move vertically, and, as the drum is turning on its shaft, the pencil attached to rod* (E) *describes a double stroke on the diagram. For a 6-inch meter the double stroke represents 2024 gallons; for a 2-inch meter,* 200 *gallons.*

Fig.2



Scale: $\frac{1}{4}^{th}$ full size.

DIAGRAM APPARATUS FOR A 6-INCH METER

Fig. 3

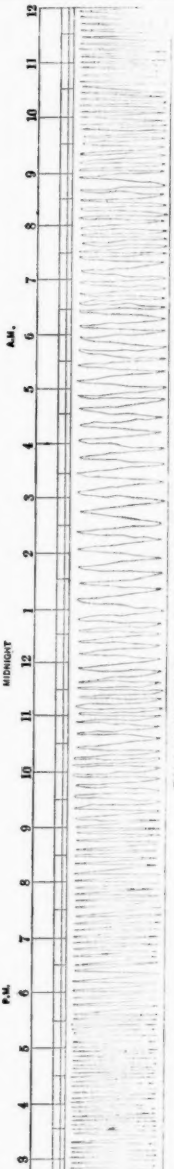


DIAGRAM FROM A 2-INCH METER

TOTAL CONSUMPTION PER DAY.

Index of Meter when diagram was put on..... 3,371,500
Index when diagram was taken off (24 hours after). 3,424,000
Total consumption per 24 hours..... 52,500 *gallons.*

NIGHT RATE PER 24 HOURS.

Consumption from 1 to 5 a.m., 200 × 13 (*number of double strokes between these hours*) = 2600 *gallons.*

Night Rate per 24 hours = 2600 × 6 = 15,600 *gallons.*

been decided upon, drawings showing these and the position of the meter were sent to the workmen's department. While the meter was being placed in position and the alterations in the piping were being made, day inspectors took the census of the district. Other day inspectors ascertained the position and condition of every house stop cock in the district, and the premises which each supplied. As it was found in the first districts that the bad state of the stop cock cases retarded the night inspectors in the subsequent ones, these received a thorough overhaul, large numbers being entirely rebuilt; in the experimental district there were 567 stop cocks; 343 of the cases on these were rebuilt, and 295 cast-iron boxes put on. In addition, considerable alterations had to be made on the lead pipes, to improve or simplify the supply to tenants.

When a district was isolated, and the meter put in working order, a few diagrams were taken to show the initial consumption, and thereafter a night inspection was made.

Night Inspection.—This is conducted as follows: The inspector puts a diagram paper on the meter a few hours before the night inspectors commence work. At midnight two inspectors begin to sound the stop cocks in the sub-district. When a noise is heard on applying the key to a stop stock, it indicates that water is passing. The inspector makes a note of this, and of the time of sounding. When no noise is heard with a stop cock full on, it is partly shut, and if water is passing the increased velocity always causes a distinct sound. Having sounded and shut all the stop cocks in the district, an interval of half an hour is allowed to elapse before opening them. The inspectors then write out a list of the stop cocks found sounding, and leave it at the office. From this a clerk prepares slips for the day inspectors. These examine the premises indicated through the sounding stop stock. The subsequent proceedings are the same as those which follow an ordinary house-to-house inspection.

At the commencement of the night inspections, much delay was caused by the bad state of the stop cock cases, but at present the district containing the largest number of stop cocks, viz., 102, can be

examined by two inspectors in about three hours and a half.

If several adjacent stop cocks sound when shut, it proves that there is a waste on the street side of the stop cocks, or on a service pipe not shut off. The position in the former case may be determined by observing which stop cock gives out most sound when shut. If on shutting one stop cock the others give no sound on being re-sounded, the inspectors retain it in their books and mark out the others.

In a night inspection of sub-district III. 1, the rate of flow of water before the inspectors began was 1,500 gallons per hour; by shutting all the stop cocks this was reduced to zero. In an inspection of sub-district IV. 3, a flow of 2,000 gallons per hour was recorded before the inspectors began; by shutting the stop cocks this was reduced to 50 gallons. And in sub-district IX. 2, a rate of flow of 2,000 gallons per hour was, by the same means, reduced to 150 gallons per hour.

It frequently happens that the rate of of flow, for a short time after the stop cocks are opened, is higher than the average night rate for the same night. This is due to the water filling the leaky service pipes, &c., which have become partly empty while the stop cocks remained shut.

Diagrams.—Diagrams were taken off each new meter every day, until the district had been put into proper order and the consumption reduced as far as possible. Thereafter three diagrams were taken of each meter on three consecutive days in every twenty-eight days, the meters being visited in rotation; and this practice obtains at present. These diagrams afford a reliable average of the consumption during the month, and show which districts are most in need of a night inspection. The inspector brings the diagrams to the office during the day; they are calculated, and the results plotted in a diagram book.

The calculation of the diagrams is somewhat laborious. The night rate is more easily obtained than that of the day, and the result is more reliable. As a rule the most confused diagrams are obtained from districts in which a considerable quantity of water is used for trade purposes.

As the first group of sub-districts has been longer in operation than the others, and as it was an experimental district, more information has been collected regarding it. After a sufficient number of diagrams had been taken to show the initial consumption in each district, the night inspections were commenced and continued every alternate night in a new district. This brought the night inspectors round to the same district at the end of three weeks, which gave sufficient time for the repairs to be made. Each night inspection was followed by a day inspection. Since there were cases in which the number of families to one stop cock was as high as 27, the source of waste was not easily traced; in addition, a certain class of fittings was found to remain tight during the day, but at night, when the pressure was highest, the fittings opened and allowed a large quantity of water to escape. These caused many fruitless visits.

The number of fittings found out of repair in the nine districts was 2,629, and comprised the following: Ball cocks, 897; screw-down cocks, 606; common ground cocks, 279; Renison's cocks, 68; lead pipes, 96; other fittings, 92. Water-closets, 591. There was 72 per cent. or the kinds of fittings allowed by the regulations of that time; 28 per cent. were of the classes proscribed in October, 1875; 350 water closets of the kinds that allow waste were found. At that time they were not proscribed, but are so now. The lead service pipes were proscribed as they weighed only 7½ and 8 lbs. per yard instead of 10 lbs. Of the 96 burst pipes, 69 were discovered by the night inspectors below ground making no show on the surface.

The distributing pipes were, with one exception, found tight.

In three cases, upon the lead service pipes being repaired, the consumption in one of the sub-districts fell 15,000, 17,000 and 12,000 gallons respectively. A small part of this may be due to other repairs being carried out at the same time.

In the experimental district, at the starting of the meters, the average rate of consumption was 59.2 gallons per head per twenty-four hours, which was reduced at the lowest to 26.6 gallons; the corresponding night rates were 45.0 and 10.8 gallons.

The results obtained in this group of districts were made the subject of a report to the Water Works Commissioners by Mr. Gale, and the system was subsequently extended to other nine districts, which were divided into forty-one sub-districts. The population at present under control is 81,289 persons; the largest number of persons to one meter is 3,310, the smallest 642, and the average 1,626. In Appendix II. some statistics are given; from which it will be seen that the average number of families to one stop cock is 6.8, and that the average number of stop cocks to one sub-district is 53.

The forty-one additional sub-districts were treated in accordance with the practice that experience proved to be the best in the experimental district. At first the night inspections were made at intervals of three weeks, and, as before, these showed the best results; they are given in Appendix III. Afterwards the night inspections were made in each district at intervals of nine weeks, irrespective of the amount of waste going on in each, so that reliable data might be obtained of the effect of close watching, and which districts would require most attention. These inspections were also for the purpose of getting as many as possible of the proscribed fittings removed.

The fittings found out of repair and wasting water in these districts were much the same as those in the experimental district: lead pipes too light to stand the pressure or unprotected from frost, and a certain class of fittings which open at night under the increased pressure, being the most fruitful sources of waste.

Results.—That this system has been a success may be seen by reference to Appendix III., in which the average results for each group of districts are given: (1) At the starting of the meters; (2) after the first three inspections were completed; (3) on the 6th of January, 1881. It may be explained in regard to the last results that, on account of frost, they indicate a somewhat higher consumption than the average of the previous year. Appendix IV. gives the averages for the year 1880.

As the tables do not show the results obtained in any of the sub-districts, a few of the more striking are given here:

Number of Dist'ct.	At Starting of Meter.		After the 3 first Inspections.	
	Total.	Night rate per 24 hrs.	Total.	Night rate per 24 hrs.
	Gallons.	Gallons.	Gallons.	Gallons.
I. 2...	81.8	64 0	34.1	9.9
I. 3 ..	68.3	45.7	31.9	15.0
II. 2...	over 70.0	over 70.0	35.5	17.5
IV. 2...	41.6	27.4	27.4	8.3
IV. 6...	61.0	55.0	47.2	23.8

In seventeen districts at the starting of the meters the consumption per head per twenty-four hours was 60 gallons or more; in eleven of these it was reduced by the three first inspections below 40 gallons. In twenty-five districts at the starting of the meters the night rate per twenty-four hours exceeded 40 gallons; it was reduced below 20 gallons by the first three inspections.

Appendix III. shows that at the starting of the meters the average consumption for all purposes was 49 gallons per head per twenty-four hours, which was reduced to 33 gallons by the first three inspections; the corresponding night rates were 37.7 and 17.5 gallons. The night rates, however, are exaggerated, on account of the pressure being much higher at night than during the day. On the 6th of January, 1881, the consumption was 35.3 gallons, which shows a saving of 13.7 gallons per head, or if the whole district under control be considered the saving is 1,114,317 gallons per twenty-four hours, equal to 1.48 gallons per head of the whole population in the area of supply. If a saving of 13.7 gallons per head was made over the whole of Glasgow and district, containing 754,778 persons, the total saving would be 10,340,450 gallons per twenty-four hours.

The operations showed almost uniformly that the quantity of water consumed increased during the nine weeks which elapsed between two inspections, and the most reliable observations gave an increase of 3.4 gallons per head on an average. The total saving per head after the first three inspections were completed was 17 gallons, so that if the consumption continued to increase at the rate of 3.4 gallons in nine weeks, the original rate of consumption would be reached in ten months and a half. In some of the districts the increase was at the rate of

only 2 gallons in nine weeks; in others it was at the rate of 7 gallons.

An instance of the gradual increase in the rate of consumption may be referred to in sub-district IV. 3, when left without inspection for three months and a half. Before the night inspection the consumption per head per twenty-four hours was 27.0 gallons, and the night rate 15.3 gallons. Fourteen days after the inspection had been made the rates were 22.2 and 10.1 gallons; six weeks after the inspection the rates were 23.3 and 9.6 gallons; ten weeks after the inspection the rates were 26.5 and 12.6 gallons; and fourteen weeks after they had increased to 28.0 and 14.9 gallons.

Cost.—The cost of the operations connected with the fifty districts was as follows:

	Total cost.			Cost per District.			Cost per 1,000 persons.		
	£.	s.	d.	£	s.	d.	£	s.	d.
Fix'g meters and altering pipes.	1,882	17	11	37	13	2	23	0	1
Repairing service stopcocks.	1,062	16	5	21	5	2	12	19	9
	2,945	14	4	58	18	4	35	19	10
Meters.....	1,372	2	2	27	8	10	16	15	3
Totals.....	4,317	16	6	86	7	2	52	15	1

The average cost of the first three inspections of each district was £12 14s. 5d., and the average cost of each of the inspections made at intervals of nine weeks, was £3 5s. 11d.

The saving of water on the 6th of January, 1881, was shown to be 1,114,317 gallons per twenty-four hours. At the cost price of the water, 20s. per 100,000 gallons, this amounts to £11 2s. 10d. per day, and as the expense is about £1 13s. per day, the daily net saving is £9 19s. 10d.

At present the attention of the night inspectors is devoted to the districts where the waste is greatest. An inspection is made on six nights in the week, each time in a new district. A day inspection follows each night inspection. Three diagrams are taken off each meter every four weeks to ascertain the consumption in the district, and in addition a diagram is taken off at each night inspection. To perform these duties one meter inspector, two night inspectors, and from two to three day inspectors are required.

The above are the principal facts regarding the system of district meters as carried out in Glasgow. It has been introduced since into London, Hull, Blackburn, Carlisle, Exeter, and other towns in England. The practice followed in these towns differs considerably from that followed in Glasgow, and as the application of the system has not been so extensive, the information regarding the sources of much of the waste has been correspondingly less. As showing the differences which obtain in applying the system to most of these towns, Carlisle and Blackburn have been selected as fairly representative of the others.

The system was introduced in Carlisle in 1876. At present there are five meters in use, controlling a population of 16,000, being an average of 3,200 persons to each meter. In a letter to the author, Mr. J. Hepworth, Assoc. M. Inst. C.E., states that the "consumption in one of the districts was 52 gallons per head of population when the meter was put in, and it was afterwards reduced to 21 gallons in consequence." Over the whole population under control of the meters, namely 16,000, the average consumption of water for all purposes was 42 gallons per head per day at the time of starting the meters; the effect of the inspections was to reduce the consumption to 21 gallons.

About once a month an inspection is made of the districts commanded by the meters. All the stop cocks are shut, so that if the meter continues to register more water than can be accounted for by small quantities passing through the stop cocks, the mains or service pipes are probably leaking and are thereupon examined.

The meters used are waste water meters. They were introduced by Mr. Hepworth because of the old service mains and pipes being worn out, and causing an enormous waste of water, which, although well known to exist, could not be discovered. Mr. Hepworth stated in his report to the water committee of Carlisle, in August, 1879, that by means of the meters 232 leakages had been discovered in the pipes during the past year, and 812 in the domestic fittings. By means

of the meters and by the gradual renewal of defective mains, service pipes and fittings, the supply which had previously been precarious, has been converted into an abundant one.

About fifteen months ago, six of Deacon's waste-water meters were put on as many districts in Blackburn, containing an aggregate population exceeding 20,000 persons.

The population of each district has not been ascertained, so that the saving per head has not been arrived at. But the extent and locality of the waste is determined by shutting the service cocks at night. If the meter continues to register more than can be accounted for by water passing through some of the defective stop cocks, the service mains are tested. On water fittings and service pipes being found defective the owners are called upon to repair them. When a sufficient time has been allowed for the repair of these a diagram is taken from the meter and compared with the one obtained before the inspection.

The night inspections are made at irregular intervals about once a week. In district No. 5, at one of the night inspections, 600 gallons of water per hour were found passing; an inspection made three days afterwards showed 4,500 gallons; on the leak which caused this being repaired, the rate was reduced to 1,200 gallons, and subsequently to 500 gallons per hour.

The table on next column, prepared by Mr. W. B. Bryan, M. Inst. C.E., shows the class of property in each district and the results of the night inspections.

Thus at the best there was a saving of 9,780 gallons per hour, or 72 per cent.

(3) *Prevention of waste by means of Pressure-reducing Valves.*—The object of pressure-reducing valves is to maintain a constant pressure in the distributing pipes, while the pressure in the mains may increase. It has been ascertained that the waste from defective pipes and fittings is much greater during the night than during the day on account of the increased pressure; to reduce this, and thereby relieve the fittings, &c., various forms of pressure-reducing valves have been applied. The older forms were worked by weights applied directly to the valve, or by means of a lever; and as the pressure applied required to be equal to

Number of District.	Class of Property in District.	Consumption of Water per hour in night.	
		At starting of Meter.	Best results after Meter was fixed.
		Gallons.	Gallons.
1	Cottage property entirely.....	530	400
2	Cottages principally; a few mills, &c.....	4,600	800
3	Houses and shops in center of town.....	2,700	600
4	Houses, cottages, shops and a few mills.....	3,500	750
5	Houses, cottages, shops and a few mills.....	1,000	500
6	Houses, cottages, shops and a few mills.....	1,200	700
	Totals.....	13,530	3,750

the difference of pressures on the opposite sides of the valve, these valves could only be applied to small pipes. Recently valves capable of being controlled by small power have been coming into use. Of these the Foulis Pressure Reducing Valve is a good example. It is similar in action to that of gas governors. An account of the various modifications of this valve, and an explanation of the action, was given by Mr. Stephen Allen, at the Glasgow meeting of the Institution of Mechanical Engineers.*

Application of the valve.—At Glasgow, in October; 1879, the valve was applied to a district commanded by a waste-water meter, and afterwards to a second. In both districts the ordinary variations of pressure in the mains is from 40 lbs. per square inch during the day to 85 lbs. at night. The valve was, in the first district to which it was applied, adjusted so that the pressure on the outlet should not at any time exceed 45 lbs. per square inch. From 4 P.M. on the day it was used to 8 A.M. on the following day the saving of water was shown by the meter diagram to be 12,600 gallons. The saving appeared to begin at 4 P.M., to go on increasing till midnight, remaining stationary till 5 A.M., and terminating at 8

*Vide Institution of Mechanical Engineers. Proceedings 1879, p. 427.

A.M. The population in this district was 2,971, so that the saving was 4¼ gallons per head per day. The night rates per head per twenty-four hours before and after the valve was fixed, were:—

	Gallons.
Average rate per head per twenty-four hours before valve was applied	24.7
Ditto, after valve was applied	15.0
Saving	9.7

The second district to which the valve was applied contained a population of 2,381. The valve in this instance was adjusted so that the pressure on the outlet should not exceed 40 lbs. on the square inch. As before, the saving began about 4 P.M. and terminated about 8 A.M. The following shows the saving effected:—

	Gallons.
Average rate per head per day from the 1st of November to the 15th of November, 1879	36.2
Valve adjusted on the 17th of November.	
Average rate per head per day from the 19th of November to the 3rd of December	28.0
Saving	8.2

The saving effected in the night rates corresponding to these was 10.8 gallons per head per twenty-four hours.

A valve similar in character to that used in Glasgow, was fitted up in Cambuslang, a village near Glasgow. Mr. W. R. Copland, M. Inst. C.E., furnishes the following particulars regarding its performance:—"This valve was fitted up about March, 1879, at a junction of a branch with the main pipe. The distributing reservoir is about 160 feet above the houses supplied through the valve, which are chiefly of the tenement class, with very inferior fittings. The main is 4 inches, the branch 3 inches in diameter; the undisturbed pressure in the main would be about 70 lbs.; and the governor is set to 30 lbs. pressure per square inch. The consumption has been taken for about a week before the governor was fitted, and it was found that to lower the level in the distributing reservoir by 6½ feet required on an average four hours and forty minutes. After the governor was fitted the experiment was repeated, and it was found that the time required averaged seven and a quarter hours, showing a saving of 35 per cent. The experiment has been several times since repeated with the same results."

Four of the reducing valves known as the "differential reducing valves," have been for some time in use in Busby, a village near Glasgow. The peculiarity in these is that the piston is of less area than the valve, and by making them of different ratios any desired pressure may be taken off; but once fixed the ratio between the outlet and the inlet pressure cannot be changed. As the pressure is too high in the village of Busby, cisterns were at first employed to reduce it, but these have been replaced by differential reducing valves. The sizes of the valves, and the extent to which each reduces the pressure, are as follow:—

8-inch valve; reduces pressure from					100 to 90 ft
6	"	"	"	"	194 " 94 "
6	"	"	"	"	70 " 10 "
5	"	"	"	"	160 " 110 "

The levels of some of the houses near the valves and supplied from the outlet side have been taken, and from these it is found that the valves perform the required reductions in pressure with great exactitude.

Conclusion.

The various methods adopted for the prevention of waste of water have proved that by far the largest proportion of waste is due to imperfect and defective fittings and service pipes, and that when for these, proper apparatus has been substituted, the waste has, in many cases, been reduced by more than one half. It has been shown that the worst classes of fittings are common ground cocks, ground ball cocks to cisterns, and water closets supplied by taps. If waste is to be prevented, screw-down cocks and "waste preventing" apparatus to cisterns must be substituted; in no case should water closets be supplied by taps. No matter what system may be employed for the detection and prevention of waste, it will be of little use if it does not embrace the removal of all defective fittings. And for securing that new fittings shall be perfect in design and workmanship, evidence appears to show that the method of keeping samples and testing and stamping is that which best meets the exigencies of the case.

Each of the three systems for detecting and preventing waste, namely, house-to-house inspection, district meters, and reducing valves, has its special uses and applications. None of them is perfect, but each becomes more nearly so on being combined with one of the other two. Taking each in order:—

(1) House-to-house inspection, combined with the practice of removing defective fittings, has been proved sufficient to reduce waste to its lowest limits, but at an expenditure of energy and money which few towns can afford. It fails to detect obscure cases of waste, such as occur underground and are continuous. In carrying it out the conscientious tenant, who takes care of his fittings, receives as much annoyance as a careless one, who allows his fittings to waste water. The system entails no check on the inspectors, and it affords no evidence as to how far their operations are a success.

(2) District meters show where most waste takes place, the locality of a leak, and the saving of water effected. The night inspections which, however, might be carried on in connection with any other system, are made at the most favorable time for the discovery of waste. As the day inspectors visit those premises only where water was found passing on the previous night, conscientious tenants receive no trouble, while careless ones receive an extra amount. In Liverpool the inspection entails visits to only one-tenth of the people that house-to-house inspection would involve. In Glasgow the proportion is about one-fifth. Add to these facts the amount of time saved, and the certainty of knowing whether the inspectors do their duty or not, and the benefits of the system are evident.

(3) Pressure-reducing valves appear to deserve more attention than they have yet received. By reducing the pressure in the lower parts of a town an increase may be made to that in the higher parts, where it is usually most required. In low-class districts, where wells are most frequent, a head pressure of a few feet is all that is required; where cottage houses, or where "tenement houses" exist, a higher pressure is needed, and for regulating the pressure to the various wants of a town the pressure-reducing valve seems eminently suitable. In all cases it relieves the fittings of pressure, and thereby removes much of the waste due to them. If the water is extensively used for power in a town, reducing valves cannot be adopted to the same extent, as they interfere with the working of the hydraulic engines. In considering meters and reducing valves it is necessary to bear in mind that the former do not prevent waste, they simply point out where it exists; the latter prevent waste but do not detect it.

In comparing the results obtained in the various towns by any system, regard must be had to the different conditions of supply which obtain; the proportion of taps, baths, water closets, and the like; the regulations as to the removal of the defective fittings, and to the difference in mode of living of the people. More especially is this the case in comparing the results obtained in Glasgow by the district-meter system with those obtained in Liverpool or elsewhere. The supply of water to Liverpool was exhausted; a new supply could not be introduced in time to ward off a dearth of water, and the Corporation were unable to procure an Act of Parliament giving them proper control over the consumers' fittings. In such circumstances Mr. Deacon applied his meter, and succeeded in so far reducing the waste that the town was restored to a state of plenty. In Glasgow the meters were started under no such conditions; the supply is in excess of the demand, and so long as this continues there is not the same necessity for expending time and money in enforcing strict economy. House-to-house inspection being in force prevents flagrant waste, and has prevented the consumption of water per head from increasing for several years. Besides house-to-house inspection, the method of testing and stamping all fittings will gradually secure fittings of first-class design and construction, and these of themselves will go far in reducing the waste. In no other town in the country having a constant water supply is there so large a proportion of fittings to the population, and as baths and water closets require a large quantity of water, there is no likelihood that the rate of consumption will be reduced to the same

point which obtains in towns not so well off for water supply.

In estimating the various methods for preventing waste, regard is had to the expense, and as this is the only matter on which corporations and water companies venture to decide what shall be done, it is natural that at first they should select that which appears least expensive. Owing to house-to-house inspection sometimes giving good results it is usually preferred, but the degrees of success which attend it are extremely various, and in no case can it be effective unless stringently carried out.

APPENDIX I.

Proscribed Fittings, Glasgow.

I. *Water closets.*—1. Lambert's cottage valve; 2. Mitchell's valve; 3. Ross' valves; 4. All kinds of cocks.

II. *Taps.*—1. Common ground cocks; 2. Renison's cocks; when these taps are supplied direct off the main.

III. *Taps on stairs and in courts*, when not self-closing.

IV. *Worn-out fittings.*—Any apparatus, when the inspector is of opinion that it is so far worn out that no permanent repair can be made.

APPENDIX II.—District Meters, Glasgow.

Number of Stop Cocks, Families, and Occupiers.

Number of district.	Number of sub-districts.	Number of stop cocks.	Number of families.	Number of families to one stop cock.	Number of occupiers at night.	Number of persons to one family.
I.	9	580	3,212	5.5	14,972	4.7
II.	6	447	2,012	4.5	10,002	4.9
III.	3	141	1,138	8.1	4,986	4.4
IV.	6	249	1,682	6.8	7,629	4.6
V.	7	260	2,294	8.8	9,815	4.3
VI.	8	318	2,998	9.4	12,614	4.2
VII.	2	162	886	5.5	4,132	4.7
VIII.	3	170	1,267	7.4	6,306	5.0
IX.	4	244	1,768	7.2	7,821	4.1
X.	2	87	708	8.1	3,012	4.2
Totals.....	50	2,658	17,965	—	81,289	—
Averages....	—	53	359	6.8	1,626	4.5

APPENDIX III.—District Meters, Glasgow.

Abstract Showing Consumption and Results of Inspection.

The quantities include all meter and trade supplies.

Number of district.	Number of sub-districts.	Number of occupants at night.	Gallons per head per day.					
			At starting of meters.		After three first inspections.		At 6th January, 1881.	
			Total	Night-rate per 24 hours.	Total	Night-rate per 24 hours.	Total	Night-rate per 24 hours.
I.	9	14,972	59.2	45.0	34.1	17.6	38.6	22.7
II.	6	10,002	65.8	60.2	42.0	27.5	44.8	28.8
III.	3	4,986	61.4	52.0	36.8	18.1	42.3	22.8
IV.	6	7,629	65.8	47.5	42.1	20.7	44.7	27.9
V.	7	9,815	45.9	30.7	31.4	14.4	29.7	15.6
VI.	8	12,614	31.0	24.6	22.6	14.8	29.1	21.9
VII.	2	4,132	37.9	25.5	34.9	21.5	31.3	20.1
VIII.	3	6,306	37.4	22.9	28.0	12.6	28.7	16.0
IX.	4	7,821	37.4	26.4	25.7	12.7	27.8	17.2
X.	2	3,012	36.8	27.8	20.8	10.7	34.5	24.3
Totals and averages	50	81,289	49.0	37.7	32.0	17.5	35.3	21.9

APPENDIX IV.—District Meters, Glasgow.

Abstract of Results of System of Night Inspection for the Year 1880.

Number of district.	Number of sub-districts.	Number of occupants at night.	Gallons of water per head per day.																							
			At starting of meters.		At Jan. 8.		At Feb. 5.		At March 4.		At April 1.		At May 13.		At June 10.		At July 8.		At Aug. 5.		At Sept. 2.		At Oct. 14.		At Nov. 11.		At Dec. 9.	
			Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night rate per 24 hours.	Total.	Night-rate per 24 hours.	Total.	Night rate per 24 hours.
I.	9	14,972	59.2	45.0	36.7	22.4	37.0	23.8	38.1	25.5	41.9	20.0	38.3	22.1	40.1	18.7	39.3	19.4	39.5	20.2	42.2	21.6	42.2	20.4	35.4	21.8	41.2	25.0
II.	6	10,002	65.8	60.2	44.1	30.9	40.3	24.7	36.9	21.9	37.4	23.1	38.6	21.9	33.8	20.0	33.9	20.4	35.2	21.5	37.1	21.8	40.1	23.1	40.8	26 2	43.5	27.9
III.	3	4,986	61.4	52.0	39.6	21.5	35.4	21.8	35.2	26.7	40.8	24.1	39.7	25.4	39.7	23.5	39.7	22.7	41.9	18.6	40.0	16.8	33.7	17.3	38.6	19.6	42.0	22.7
IV.	6	7,629	65.8	47.5	42.8	26.8	36.7	22.5	37.2	18.9	38.9	19.5	34.0	20.0	44.0	27.4	46.1	24.7	42.1	27.1	52.8	25.5	45.8	27.0	45.1	25.3	45.3	27.3
V.	7	9,815	45.9	30.7	29.3	15.6	29.6	16.7	30.1	15.5	35.4	19.3	31.0	13.3	33.6	15.7	35.4	16.9	33.7	14.1	36.1	15.8	36.0	16.6	36.9	20.6	32.7	16.8
VI.	8	12,614	31.0	24.6	27.9	20.1	29.0	22.3	31.9	24.3	29.0	19.8	27.8	16.5	29.2	17.1	28.2	16.3	29.5	16.9	28.4	15.9	31.6	17.4	27.3	17.0	31.2	23.0
VII	2	4,132	37.9	25.5	31.4	21.1	32.2	24.2	33.9	24.7	30.6	17.7	31.2	17.3	31.0	17.8	29.7	21.2	32.9	21.2	28.4	22.1	35.3	19.5	32.6	21.5	37.1	26.5
VIII.	3	6,306	37 4	22.9	24 7	12.9	26.7	17.3	28.5	14.7	27.2	14.7	29.1	16.5	30.3	16.3	28.1	13.9	30.5	14.6	32.5	18.8	32.6	18.1	29.3	17.4	31.2	17.3
IX.	4	7,821	37.4	26.4	28.0	15.2	29.4	20.1	33.3	22.5	31.6	19.7	31 4	19.2	34.9	19.0	32.0	16.5	36.0	20.3	33.3	16.2	34.9	18.4	30.7	18.2	31.4	20.0
X.	2	3,012	36.8	27.8	28.2	16.3	28.4	21.5	24.0	15.4	28.4	18.2	30.1	19.0	32.5	16.3	31.0	17.0	38.7	24.4	35.2	18.9	34 2	19.5	30.5	18.5	28.2	16.1
	50	81,289	49.0	37.7	34.5	20.9	32.9	21.6	33.5	21.6	34 2	19.8	33.2	19.1	35.1	19 1	34.3	18.8	35.4	19.5	37.1	19.3	36.9	19 8	34.9	20.8	36.8	22.8

THE SOIL AND ITS INFLUENCE ON HUMAN HEALTH.

From "The Builder."

At the recent meeting of the German Society of Natural Philosophers and Physicians at Saltzburg, the eminent Dr. Pettenkofer read a valuable paper on the subject of the influence of the soil upon human health. The subject, he said, was one of the oldest in sanitary science, but it possessed of necessity a permanent interest, as it was constantly presenting itself under new aspects. The soil, the air, and the water had been from time immemorial regarded as the principal factors in the problem of the salubrity of localities. It was these which made a place healthy or the reverse. In recent times there had, in Dr. Pettenkofer's opinion, been a tendency to look too exclusively to the air and water, and to neglect the influence of the soil in sanitary questions. But the ground on which men built their houses, and on which they passed their lives, must always take a pre-eminent place in the determination of all sanitary problems. Dr. Pettenkofer pointed out that air is almost invariably in motion. The average speed at which it moves over the ground at the earth's surface is about 10 ft. per second. Even in a so-called calm, the air is not still; it is still moving at the rate of about 1ft. 6in. per second. Hence, even in abysses, and the most secluded valleys of the country, or the narrowest lanes of cities, the air is never really stagnant. Nearly the same may be said with regard to water. All water as it falls from the clouds is of nearly homogeneous composition. It is but very slightly impure. From the soil, however, water, like air, takes up certain impurities. These are generally removed from the air much more quickly than from the water. The circulation of water and its purification from foreign elements are more complicated and less expeditious matters than in the case of air. Nevertheless the process of purifying water goes on even in the drains and sewers of cities, but more especially in the great natural drains, the rivers,—like the Isar, at Munich; the Elbe, at Dresden and Hamburg; the Thames, at Oxford and London; or the Seine, at Paris and Rouen. It was in the soil that impurities were most obstinately and longest retained. The influence of the soil showed itself most clearly in the case of epidemic diseases. Malaria has always been recognized as dependent on the soil of the localities where it is found. But it was not less true that cholera, typhus fever, yellow fever, perhaps even the plague itself, likewise depended on, or were connected with, the condition of the soil. What we have still to settle is the question, "How?" It has been attempted to explain the epidemic appearance of such diseases by assuming that they were propagated through the air or water, or both. But it is incorrect to regard either air or water as the true cause of epidemics. This is generally to be found in the soil. One proof of this Dr. Pettenkofer found in the fact that ships at sea were inaccessible to cholera. It had been observed that when persons were attacked by cholera on the high seas, only those who came from the same localities caught the disease, while the other passengers escaped. It was only exceptionally that the epidemic broke out on board a vessel, and then only when the passengers and crew were in frequent contact with an infected locality on shore. But even on land there were places safe against epidemics. Thus, Lyons, in the south of France, in spite of its large traffic with Paris and Marseilles, where cholera was raging, remained free from the disease. The only explanation that could be found was the condition of the soil or ground at the former city. Still more surprising was the immunity of Versailles from cholera, when Paris, with which it was in constant and immediate communication, was the scene of an outbreak of that epidemic. The investigations of the German Commission on Cholera have clearly shown that epidemics are localized, and that they are caused by the condition of the soil.

What is that, asked Dr. Pettenkofer, in the condition of the soil which

is able to produce such an effect upon the health? He answered that probably it would be found in a vast number of minute infinitesimal organisms,—so minute that millions of them might, if collected, lie on the head of a pin. Dr. Nageli has distinguished such organisms, and presented a faithful and vivid picture of them as they rise from time to time out of the ground. He makes a distinction between soil that is pestilential or unhealthy, and soil that is healthy or free from pestilence. This distinction does not coincide with the presence or absence of a certain kind of fungus, as this is found growing everywhere. However, if the disease is attributable to the same species of fungus generally found growing in every place, then the same forms of these little organisms must produce different effects under different circumstances. It is the task of hygienic science to examine the conditions of the soil favorable to the development of these organisms and their entrance into the human system. It has long been known that by means of drainage and cultivation or tillage an injurious unhealthy soil, like that of the malaria districts, may be deprived of its dangerous character. Even in ancient times canals were cut by the Romans in order, by drainage, to reduce the evil effects of the malaria, though these works had subsequently been destroyed and forgotten. Certain diseases have their favorite haunts in alluvial soil on account of the porous nature of that soil. The spaces and interstices of this soil favor the circulation of air and water. But the same may, to a certain extent, be said of some kinds of porous rock, as is proved by the appearance of cholera in rocky places like Malta. Exact investigation respecting the air in soils have shown its importance from a sanitary point of view. On thoroughly dry soils the ground air does not absorb any more carbonic acid or organic matter than the air above the ground. This has been shown by experiments with the air brought by Dr. Zittel from the Libyan Desert. The subterraneous or underground air circulates in the soil, although but slowly. During the greater part of the year it penetrates into badly-built dwellings, and conveys them into the fungous germs of disease. In this manner the soil influences human health, and there are only too many dwellings subject to this influence, which is the more baneful the worse they are ventilated. Our houses, in fact, draw or suck the air out of the ground like so many cupping glasses. From a hygienic point of view they are, indeed, less rational than the old pine dwellings of primeval humanity, or than even the village cottages of the present day, whose floors are covered with mud plaster. This was illustrated in the case of an outbreak of cholera at Dantzic, where out of a group of nine cottages, seven modern-built ones, with cellars and plank floors, were visited by the epidemic, while the only two with mud plaster escaped. Accordingly, it appears that in our houses we must pay more attention to the soil on which they are built. Such arrangements should be made in their construction that we should no longer be compelled to take to flight when an epidemic breaks out. A proper method of sanitary construction would enable us to withstand successfully a siege, so to speak, by the cholera, in which case it could be said with greater truth than ever that "a man's house is his castle," Dr. Pettenkofer regards it as the duty of Governments to take the initiative in this matter. Not less important than the air is the water. All organisms require moisture. There are two degrees of moisture to be distinguished: first, that in which the pores of the soil are occupied by air and water in common; and, secondly, that in which the water has entirely driven out the air. In the first case, we have a damp soil; in the second, we have underground water. The intimate connection between typhoidal diseases and the underground water has been long recognized. When underground water rises higher than the average, typhus disappears, but when again the water in question sinks below its average level, typhus increases. This had been shown clearly by observations made in Berlin. Any apparent exceptions such as places visited by typhus, though without underground water, yet having a porous soil, or again the unimportance of the level of underground water near rivers, did not invalidate the argument. As, amongst us in Europe, the abdominal typhus fever depends on

the rainfall and the level of the underground water, so in India does the cholera depend precisely upon the like causes.

With regard to the theory attributing cholera, typhus, and all zymotic diseases mainly to the water we drink, Dr. Pettenkofer advanced some arguments against its unconditional acceptance. The malaria poison, for instance, does not enter the water. The *baccillus malariæ* has been proved to be an organism living in the air, not in the water, of the infected districts, and it was from the air that they penetrated into the human system, and ultimately into the blood. The real cholera germ has not yet been accurately ascertained or identified. It is still doubtful whether it is disseminated more by water than by air. The drinking water of places visited by cholera has often been entirely given up without preventing the re-appearance or continuance of the epidemic. The city of Basle, for instance, possesses the purest drinking water which is brought down from the Jura, but has not been protected by it from the disease. Dr. Pettenkofer, however, would not question the importance of the water we drink, in regard to this question. Far from denying the value of good waterworks, the speaker dwelt on the importance of pure drinking water. The *bacteria* question, too, was one of the highest importance, but the theoretical deductions on that subject required to be practically employed and confirmed by practical experiments. To the observations of a Pasteur there needed to be added the practical applications of a Lister, in order to make them of value in sanitary or surgical science, and in the same way mykological investigations would require to be completed by hygienic researches. It had been observed that in the case of very concentrated and very diluted fluids used as nutriment, the very small organisms usually found in those fluids in their normal condition are destroyed. An inference drawn from this, that dirt is no danger to health, provided it be only thoroughly concentrated dirt, could not be admitted. In villages the dirt is not stronger or more genuine dirt than in towns. In the latter it is only covered up more, and, therefore, the more dangerous. In villages, too, the more cleanly dwellings were the healthier. But granting that concentrated dirt may hinder fungous vegetation, there still remains for hygienic science the task of ascertaining what must be the proper degree of this concentration, and to consider the conditions favorable to the injurious vegetation in question. Sanitary science was, in fact, one unceasing battle against dirt. As the growth of these minute fungi is increased by moisture, it might be thought that all would be right if everything were kept from the damp. However, we are not able to prevent everything from becoming damp or to prevent the dissemination of germs in a thousand different ways. It is in any case good to avoid or to draw off moisture. Dr. Pettenkofer strongly condemned the use of ground reservoirs for rain water and other such pits, as they contribute to keep the soil thoroughly moist, and are thus very injurious in the neighborhood of dwelling-houses. They serve, in fact, precisely like a sort of artificial inundation.

The doing away with the moisture or dampness of soils, or at least the diminution of damp, is the main advantage of the various systems of drainage. The value of drains might be exaggerated, but we must beware of under-estimating them. Statistics prove that every city which has laid down a system of drainage has greatly benefited thereby. Further, Dr. Pettenkofer referred to the self cleansing process going on in the soil through the agency of certain very low organisms. The formation of saltpeter through certain fungous growths, shows that these minutiæ are capable of acting not only injuriously, but also beneficially. Hygienic science, at the present moment, stands in view of a practically boundless world of possibilities. But this must not discourage us from action. Hitherto, hygienic science has been guided chiefly by feeling, instinct, and so-called common sense; it is only recently that it has been established on a scientific basis. Cleanliness plays in public life an important part. Cleanly persons live longer and more healthy than the dirty. We ought to respect the sanitary system in common use, even though it still lacks a scientific foundation. But scientific criticism is

necessary to refute false ideas, and to get rid of what is superfluous and hurtful. In conclusion, the speaker said that the advancement of sanitary and hygienic science, both in theory and practice, was one of the most important duties of the State.

THEORY FOR TURBINE WATER WHEELS.

By GUSTAF ATTERBERG.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

I.

In Sweden I often have been employed about the construction of turbine water wheels, but have never been satisfied with the theories for these motors; therefore I have now tried to make a more practical one. Since there are a great number of theories for these motors, there is no need of giving the derivations of the equations, unless they differ from those used by other authors. I have thus tried to make the treatise as short as possible and at the same time practical.

I know it has often happened, that turbines have been made for the most economical use of the water, but, when made and tried, they did not give so much power as was expected, and sometimes they gave very low efficiency, although the theoretical conditions for the best efficiency seemed to be correct. Then they thought that the friction between the water and the wheel was greater than they at first supposed it to be, although the assumed value for this friction was perhaps very high; and in order to obtain good efficiency they often gave the vanes a finished surface, but even then they did not obtain the gain expected. Then many thought that turbines could not give good efficiency or that the theories were not practical.

That several turbines gave more efficiency than usual happened only by change, as the theories used for them were more or less wrong, which everybody can easily see by looking at the theory which now will be published.

The conditions, which ought to be satisfied in order to obtain good efficiency, will now be mentioned in connection with some discussions of the motion of the water in the turbines.

The loss of efficiency, by the friction of the water, is of such a value, that it may be neglected, unless the distance between the vanes is too small or the relative velocity of the wheel is too great, which two cases never occur in practice. The distance through the wheel is very unimportant, compared with the head of the water, and therefore this loss of efficiency cannot have so great a value, as it it supposed to have. The motive for assuming so great a value for this loss of efficiency is, in my opinion, to be found in other neglected losses, and from wrong theories.

The space between the guide case and the wheel causes no, or very unimportant, loss of water; because the water passes through the wheel with great velocity, and in consequence with a great momentum. When it passes by this space the internal pressure (p_1) of the water tends to deflect its course through the opening; but in the short time required to traverse this distance, it cannot perceptibly change its direction, and it passes by the space and cannot pass through. The volume of water, that perhaps can come through this space, is unimportant in comparison with the volume that passes through the wheel. The wheels can thus be calculated without consideration of this loss. Should the pressure in the water be lower than the pressure of the atmosphere, according to the same reasoning, no air can come in through the space, if the width at the inlet of the wheel is some less than the width at the outlet of the guide case.

The normal velocity of the water, at the inlet of the wheel, ought to be the first consideration for the further calculation of the wheels; because on its value depends the dimensions of the wheels at the inlets and also the efficiency of the wheels. The less this velocity is the

higher efficiency one can get; but this velocity cannot be very low, because the wheels then become of impracticable dimensions.

The vanes in the wheel ought to have the least possible thickness. Since the water has a great velocity it cannot instantly change its direction, and in consequence, when the water is obstructed by the vanes an impact by the water must be produced. Even if the edges of the vanes are very thin this impact may occur, and if it should not occur, a loss of efficiency would arise; because the water would take a partial motion in both directions from the vanes, according to their thickness, and a part of the natural power must be used to produce those motions. The maximum of this loss of efficiency is:

$$(1-\xi_1).\left(\frac{c_1}{c}\right)^2.\sin^2\alpha$$

when ξ_1 is a value that indicates what part of the inlet of the wheel the openings take, according to the thickness of the vanes, c_1 is the velocity of the water when it flows out from the guide case, c is the velocity which a body obtains by falling a distance equal to the whole head of the water, and α is the angle between the guides and the periphery of the wheel. The loss is expressed in proportion to the natural power. Set the value:

$$\frac{c_1}{c}=\sqrt{\mu}$$

then μ indicates, what part of the head of the water is used in order to give the water the velocity c_1 between the guides. The value of the loss is then:

$$(1-\xi_1).\mu\ \sin^2\alpha \quad . \quad . \quad . \quad . \quad . \quad (1).$$

The value of this loss depends only upon the judgment of the designer and is accordingly not taken into further account.

The water ought to flow through the wheel with a continually diminishing velocity, in such a manner as if there were an immense number of vanes. Such a flow of the water can be obtained by use of only a few vanes, if they are constructed in the manner shown in the following pages. Turbines ought not to be so constructed that the openings between the vanes will not become completely filled with water, because in such a case irregular motions in the water would occur. Then the wheels ought not to be called turbines, but only water wheels.

The width at the outlet of the wheel ought not to be too large, because the water perhaps cannot then obtain such a motion as required, and also perhaps cannot completely fill the openings between the vanes. If the width at the outlet of the wheel is larger than at the inlet, then the velocity (c_2) with which the water leaves the wheel diminishes, but the velocity with which the water spread increases. These two velocities make only losses of efficiency, and their sum ought to be as little as possible.

The water cannot spread in the wheel without a power to cause this spread, and unless impact and irregular motions occur, there is only one cause for the spread of the water, namely, the internal pressure of the water. This pressure depends upon the fact that the water flows between the guides with a velocity less than the velocity which corresponds to the whole head of the water, and also from the height between the upper surface of the water and the inlet of the wheel. If this internal pressure (p_1), is less than the pressure of the atmosphere, then ought the width at the inlet of the wheel be a trifle less than the width at the outlet of the guide case, in order to prevent the air coming in through the space between the guide case and the wheel. In the other case the pressure of the atmosphere will counteract the internal pressure of the water. The less this internal pressure is the less ought the difference between the widths at the inlet and at the outlet to be.

When the water flows through the wheel the value of the velocity with which it spreads ought to have a gradually increased value.

The Spread of the Water in a Turbine Wheel.—Fig. 1 is obtained by passing a plane, with its rectilinear elements parallel to the axis of the wheel, through the path which a particle of water would describe in passing through a radial turbine wheel, and developing the surface thus obtained. The line gh thus represents the length of the path, one particle moving in the center line of the cross section of the wheel describes. Such a shape of this surface is easily obtained if we assume that the velocity of the water relative to the vanes ought to have

a gradually increased value; but a wheel ought not to be made in this way. If the absolute velocity of the water has a continuously diminished velocity, and the particles of the water move in lines curved in only one direction, and then if the velocity relative to the vanes is sometimes increased and sometimes diminished, there is no loss of efficiency, because those velocities are only relative. Such a flow of the water as Fig. 1 represents ought thus to be avoided, and another obtained that gives a better flow. If it is assumed that the water flows as Fig. 1 indicates, it is easy to see that the sheet of water that comes into the wheel at c, has a velocity towards the line gh, and this velocity diminishes finally to the point d, where the water has lost all velocity in this direction. The loss of energy that corresponds to this loss of velocity is to be found as heat in the water. From the point d the water again obtains such a velocity; but now in direction from the line gh, and it obtains its maximum at the point e. The energy that corresponds to this velocity is delivered in its passage from the point e to the point f, because at this point the water has lost all velocity in this direction, and is converted into heat in the water. Should the water come into this wheel without velocity towards the line gh, an impact would arise against the sides of the wheel, because the water cannot instantly change its direction. From this it is easy to understand that those changes of velocities of the water ought to be avoided. In order to make these losses of efficiency as unimportant as possible the water ought to have, as before asserted, a gradually increased velocity from the symmetry plane gh, and it obtains its maximum at the outlet of the wheel. This maximum ought to be as little as possible, which takes place if the surface *aabb* in Fig. 1 has such a form as the surface *aaff* in Fig. 5.

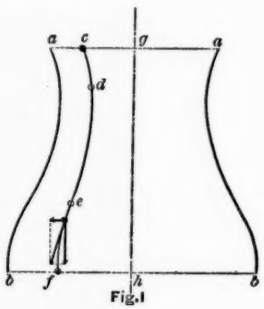


Fig. 1

If the internal pressure of the water is less than the pressure of the atmosphere, the width at the inlet of the wheel ought to be slightly less than the width at the outlet of the guide case, in order to prevent the air coming into the wheel, so that the water can spread as required.

THEORY FOR RADIAL TURBINE WHEELS.

The notations used in this theory are:

μ = a value that indicates what part of the head of the water is used to give the water the velocity (c_1) between the guides.

c = the velocity that corresponds to the whole head of the water.

c_0 = the velocity with which the water enters the penstock that conveys the water to the wheel.

c_1 = the velocity of the water when it enters the wheel.

c_2 = the velocity of the water in a plane normal to the axis, when it leaves the wheel.

c_3 = the velocity of the water with which it discharges at the lower surface of the water.

U_1 = the relative velocity of the water when it enters the wheel.

U_2 = the relative velocity of the water in a plane normal to the axis when it leaves the wheel.

V_1 = the velocity of the wheel at the inlet.

V_2 = the velocity of the wheel at the outlet.

N_1 = the normal velocity of the water when it discharges from the guide case.

N_2 = the normal velocity of the water when it leaves the wheel.

r_1 = the radius of the wheel at the inlet.

r_2 = the radius of the wheel at the outlet.

$m = \frac{r_2}{r_1}$

B_1 = the width between the sides of the wheel at the inlet.

B_2 = the width between the sides of the wheel at the outlet.

a=the angle between the directions of the velocities c_1 and V_1.

β=the supplement to the angle between the directions of U_1 and V_1.

γ=the supplement to the angle between the directions of U_2 and V_2.

φ=the supplement to the angle between the directions of c_2 and V_2.

θ=the angle (*eoe*) between the curves of the sides of the wheel and the center line of the cross section of the wheel measured at the outlet of the wheel. See Fig. 4.

H=the effective head of the water.

h_1=the height between the upper surface of the water and the inlet of the wheel.

h_2=the vertical distance between the inlet and the outlet of the wheel.

h_3=the height from the outlet of the wheel to the lower surface of the water.

p_0=the pressure of the atmosphere per unit of surface.

p_1=the internal pressure of the water when it enters the wheel.

p_2=the internal pressure of the water when it leaves the wheel.

δ=the weight of the water per unit of volume.

(1 cubic meter=1,000 kilograms or 1 cubic foot=62.4 pounds.

η=the relative efficiency of the wheel.

L=1−η=the relative loss of efficiency of the wheel.

ξ_1=a value that indicates what part the openings between the vanes are of the inlet of the wheel, according to the thickness of the vanes.

ξ_2=a similar value at the outlet of the wheel.

t=the time used for a particle of water to pass through the wheel.

t_x=the time used for a particle of water to pass through the part of the wheel enclosed between the radius r_1 and the arbitrary radius x.

x=an arbitrary radius.

A=the surface enclosed between the sides of the wheel and the distances r_1 and r_2, which surface is obtained if the wheel is supposed to be cut by a plane through the axis of the wheel.

A_x=a similar surface enclosed between the sides of the wheel and the distances r_1 and x.

a=the distance from the center of gravity of the surface A to the center of the wheel.

a_x=the distance from the center of gravity of the surface A_x to the center of the wheel.

ξ_x=the value of ξ that corresponds to the radius x.

ξ=the mean value of ξ for the wheel.

ξ''=the mean value of ξ for the part of the wheel between the radii r_1 and x.

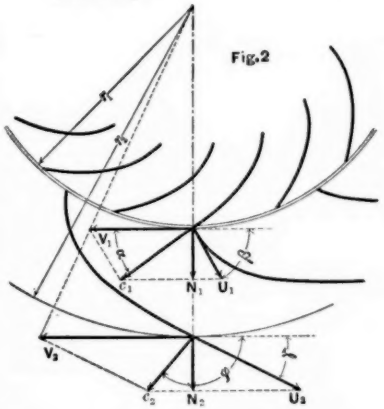
S_x=the removing of the water which takes place at the distance x from the center of the wheel, according to the reaction of the wheel.

Y_x=the distance one point of the wheel at the distance x from the center of the wheel moves during the time t_x.

n=number of revolutions of the wheel per minute.

Q=the volume of water that flows through the wheel per second.

g=the acceleration of gravity (=9.82 meter per second, or 32.2 feet per second.)



$\sqrt{\mu}\sin a$=a constant that indicates the value of the normal velocity of the water at the inlet of the wheel compared with the velocity that corresponds to the whole head of the water.

The unit of time is one second.

The connection between the values of the angles and the velocities of a wheel are obtained from Fig. 2, according to the laws of the velocities, and are:

$$c_1 = c.\sqrt{\mu} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

$$U_1 = c.\sqrt{\mu}.\sin\alpha.\frac{1}{\sin\beta} \quad . \quad . \quad . \quad . \quad . \quad (3).$$

$$V_1 = c.\sqrt{\mu}.\sin\alpha(\cot\alpha+\cot\beta) \quad . \quad . \quad . \quad (4).$$

$$N_1 = c.\sqrt{\mu}.\sin\alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5).$$

$$c_2 = c.\sqrt{\mu}.\sin\alpha.\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}.\frac{r_2}{r_1}.\frac{1}{\sin\varphi} \quad . \quad (6).$$

$$U_2 = c.\sqrt{\mu}.\sin\alpha\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}.\frac{r_2}{r_1}.\frac{1}{\sin\gamma} \quad . \quad (7).$$

$$V_2 = c.\sqrt{\mu}.\sin\alpha(\cot\alpha+\cot\beta).\frac{r_2}{r_1} \quad . \quad . \quad . \quad (8).$$

$$N_2 = c.\sqrt{\mu}.\sin\alpha.\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}.\frac{r_2}{r_1} \quad . \quad . \quad . \quad (9).$$

It is to be observed that

$$\sin\alpha = \frac{1}{\sqrt{1+\cot^2\alpha}}$$

when α is an arbitrary angle and thus is obtained:

$$\mu = \mu\sin^2\alpha(1+\cot^2\alpha) \quad . \quad . \quad . \quad . \quad . \quad (10).$$

The value of the loss of efficiency caused by the spread of the water.—In order to find this loss we assume that the water flows through the wheel in such a way as Fig. 5 indicates. The distance one particle of water has to traverse in its passage through the wheel, is the distance $a'e'$, if the point e' is at the distance r_2 from the center of the wheel. The length $a'e' = ae$, see Fig. 3 is approximately

$$a'e' = \pm(r_2 - r_1).\frac{1}{\sin\alpha}$$

which value is always positive. If the curve ae, see Fig. 5, is a parabola, then is

$$\text{tang}\,\theta = \pm\frac{B_2-B_1}{r_2-r_1}.\frac{\sin\alpha}{\sin\varphi} \quad . \quad . \quad (11).$$

which value is always positive, and which value is easily found from the figures 3, 4 and 5. Assume that a sheet of water, of the thickness dz, discharges at a distance z from the center line ae, see Fig. 4. Its volume is then:

$$dQ = \frac{dz}{B_2}.Q$$

Its velocity of spread is evidently:

$$N_2\,\text{tang}\,\theta_z$$

The value of tang θ_z is easily found to be:

$$\text{tang}\,\theta_z = \frac{2z}{B_2}.\text{tang}\,\theta$$

and thus is the velocity of spread:

$$N_2.\frac{2z}{B_2}\text{tang}\,\theta$$

From the equations (6) and (9) is obtained:

$$N_2 = c_2\sin\varphi$$

By use of this value and also of the equation (11) the velocity of spread is found to be:

$$\pm c.\frac{2z}{B_2}.\frac{B_2-B_1}{r_2-r_1}.\sin\alpha.$$

The momentum of the water when it discharges from the wheel is a loss of efficiency, and if this loss is expressed in proportion to the natural power, then is the loss by the spread of the water:

$$\frac{1}{Q.\delta.H}.\int_{-\frac{B_2}{2}}^{+\frac{B_2}{2}}.\frac{1}{2}.\frac{dz}{B_2}.\frac{Q}{g}.\delta.c_2^2.\left(\frac{2z}{B_2}\right)^2.\left(\frac{B_2-B_1}{r_2-r_1}\right)^2.\sin^2\alpha \quad . \quad . \quad (12).$$

because $Q\delta H$ is the natural power of the water. The value of H is, when expressed in c:

$$H = \frac{c^2}{2g} \text{ or } c = \sqrt{2gH} \quad . \quad . \quad (13).$$

From the equations (12.) and (13.) is obtained after some transformations the loss by the spread to be:

$$\frac{4}{B_2^3}.\left(\frac{B_2-B_1}{r_2-r_1}\right)^2.\sin^2\alpha.\left(\frac{c_2}{c}\right)^2\int_{-\frac{B_2}{2}}^{+\frac{B_2}{2}}z^2dz$$

or after the integration:

$$\frac{1}{3}\left(\frac{B_2-B_1}{r_2-r_1}\right)^2.\frac{1}{1+\cot^2\alpha}.\left(\frac{c_2}{c}\right)^2$$

The loss of efficiency of a turbine wheel is then:

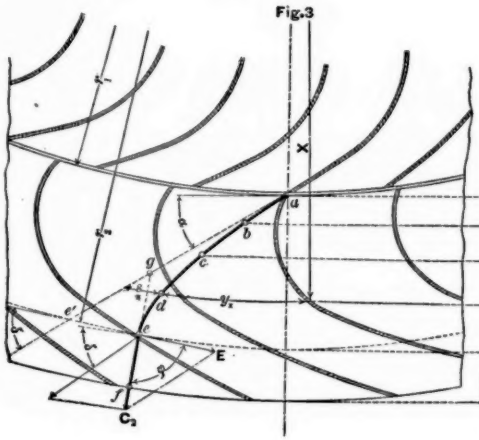
$$L = \left(\frac{c_2}{c}\right)^2 + \frac{1}{3}\left(\frac{B_2-B_1}{r_2-r_1}\right)^2.\frac{1}{1+\cot^2\alpha}.\left(\frac{c_2}{c}\right)^2$$

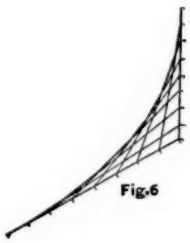
or:

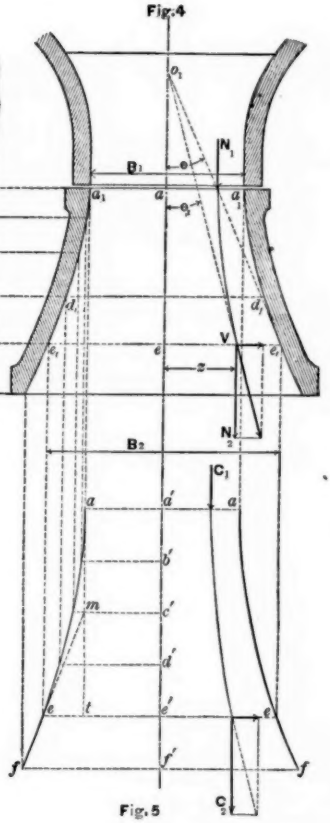
$$L = \left(\frac{c_2}{c}\right)^2\left\{1+\frac{1}{3}\left(\frac{B_2-B_1}{r_2-r_1}\right)^2.\frac{1}{1+\cot^2\alpha}\right\}. \quad (14).$$

if it is assumed that the losses of efficiency by the impact of the water against the vanes, the friction between the water and the wheel, and the leak through the space between the guide-case and the wheel are so unimportant that they can be considered of no value. It then remains to find the values of the dimen-

I. The equation which gives the connection between the dimensions at the inlet and at the outlet of the wheel is obtained, if it is expressed by an equation that the sum of the openings at the inlet of the wheel, multiplied by the normal velocity of the water at the inlet, is equal to the sum of the openings at







sions of the wheel, that makes equation (14.) of as little value as possible. The value of the loss of efficiency by the spread is very slight and can be neglected in practice, and then:

$$L=\left(\frac{c_2}{c}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (14).'$$

The derivations of the equations that must be satisfied for all turbines are now to be mentioned:

the outlet of the wheel, multiplied by the normal velocity of the water at the outlet, or

$$Q=2\pi r_1 B_1 \xi_1 N_1=2\pi r_2 B_2 \xi_2 N_2$$

By use of the equations (5.) and (9.) is obtained:

$$\frac{c_2}{c}=\frac{\xi_1}{\xi_2}\cdot\frac{B_1}{B_2}\cdot\frac{r_1}{r_2}\cdot\frac{\sqrt{\mu}\sin\alpha}{\sin\varphi} \quad . \quad . \quad . \quad (15).$$

II. The geometrical connection be-

tween the angles and the velocities is obtained by use of equation (6.) and is:

$$\frac{c_2}{c}=\sqrt{\mu}\sin\alpha.\frac{r_2}{r_1}\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}.\frac{1}{\sin\varphi}$$

Another not so complicated may be used instead, obtained from equations (6.) and (15.), and is:

$$\cot\alpha+\cot\beta=\frac{1}{m^2}.\frac{\xi_1}{\xi_2}.\frac{B_1}{B_2}(\cot\gamma-\cot\varphi)(16)$$

This equation gives a hitherto unknown relation of great simplicity between the angles and the other dimensions of a wheel.

III. According to the laws for the motion of the water, for the flow of the water from the upper surface of the water to the inlet of the wheel the following equation is obtained:

$$\frac{c_0^2}{2g}+h_1+\frac{p_0}{\delta}-\frac{p_1}{\delta}=\frac{c_1^2}{2g}$$

or:

$$h_1=\frac{c_1^2}{2g}-\frac{c_0^2}{2g}-\frac{p_0}{\delta}+\frac{p_1}{\delta}\quad\ldots\quad(17).$$

The value of $\frac{p_1}{\delta}$ is then:

$$\frac{p_1}{\delta}=h_1+\frac{c_0^2}{\delta}-\frac{c_1^2}{\delta}+\frac{p_0}{\delta}\quad\ldots\quad(18).$$

When the water flows through the wheel then is according to the laws for the discharge of water from vessels that are in motion:

$$\frac{U_2^2}{2g}-\frac{U_1^2}{2g}=\frac{V_2^2}{2g}-\frac{V_1^2}{2g}+h_2+\frac{p_1}{\delta}-\frac{p_2}{\delta}$$

or:

$$h_2=\frac{U_2^2}{2g}-\frac{U_1^2}{2g}-\frac{V_2^2}{2g}+\frac{V_1^2}{2g}-\frac{p_1}{\delta}+\frac{p_2}{\delta}.\quad(19).$$

If the turbine is made in such way that the water discharges into the air when it leaves the wheel, then is $p_2=p_0$. The value of H is then:

$$H=h_1+h_2$$

If the turbine is made in such a way that the water flows from the upper surface of the water to the lower through a penstock, through the wheel, and again through a penstock, and discharges under the lower surface of the water, or the water discharges from the turbine into the tail-race under the lower surface of the water—(see Fig. 7)—then is $H=h_1+h_2+h_3$. The values of h_2 and h_3 can often have negative values (see Fig. 7). Also the value h_1 can be negative;

$H=h_1+h_2+h_3$ then is

$$\frac{c_2^2}{2g}+h_2+\frac{p_2}{\delta}-\frac{p_0}{\delta}=\frac{c_3^2}{2g}$$

or:

$$h_2=\frac{c_3^2}{2g}-\frac{c_2^2}{2g}-\frac{p_2}{\delta}+\frac{p_0}{\delta}\quad\ldots\quad(20).$$

The value of $\frac{p_2}{\delta}$ is then:

$$\frac{p_2}{\delta}=\frac{c_2^2}{2g}-\frac{c_3^2}{2g}+\frac{p_0}{\delta}-h_2\quad\ldots\quad(21).$$

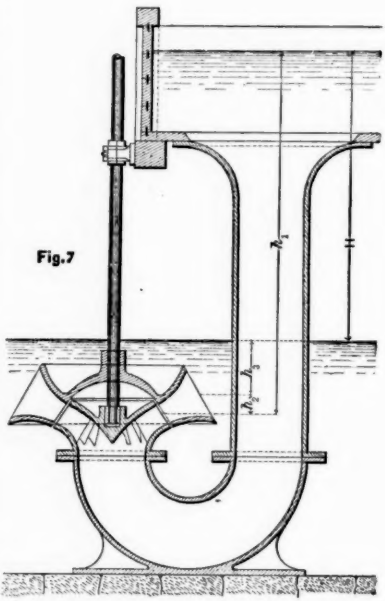


Fig. 7

The values of p_1 and p_2 ought never to be so small as to be nearly equal to zero, and should usually be not less than p_0.

For turbines where the water discharges into the air.—

$$H=h_1+h_2$$

$$H=\frac{c_1^2}{2g}+\frac{U_2^2}{2g}-\frac{U_1^2}{2g}-\frac{V_2^2}{2g}+\frac{V_1^2}{2g}-\frac{c_0^2}{2g}$$

according to the equations (17) and (19). By use of equation (13), and by assuming the value of c_0 as of no value, after some transformations.

$$\left(\frac{U_2}{c}\right)^2=1-\left(\frac{c_1}{c}\right)^2+\left(\frac{U_1}{c}\right)^2+\left(\frac{V_2}{c}\right)^2-\left(\frac{V_1}{c}\right)^2$$

By use of the equations (2), (3), (4) and (8) is obtained:

$$\left(\frac{U_2}{c}\right)^2=\mu\sin^2\alpha\left\{\frac{1}{\mu\sin^2\alpha}+m^2(\cot\alpha+\cot\beta)^2-\right.$$
$$\left.-2\cot\alpha(\cot\alpha+\cot\beta)\right\} \quad . \quad (22).$$

From equations (6), (7) and (15) is obtained:

$$\frac{U_2}{c}=\frac{\sqrt{\mu}\sin\alpha}{\sin\gamma}\cdot\frac{\xi_1}{\xi_2}\cdot\frac{B_1}{B_2}\cdot\frac{1}{m} \quad . \quad . \quad (15').$$

By use of equations (15'), (16) and (22) is obtained:

$$\cot\gamma=\frac{\cot^2\varphi-1+2\cdot\frac{\xi_2}{\xi_1}\cdot\frac{B_2}{B_1}\cdot\cot\alpha\cdot\cot\varphi+\left(\frac{\xi_2}{\xi_1}\right)^2\cdot\left(\frac{B_2}{B_1}\right)^2\cdot\frac{m^2}{\mu\sin^2\alpha}}{2\left(\cot\varphi+\frac{\xi_2}{\xi_1}\cdot\frac{B_2}{B_1}\cot\alpha\right)}$$
$$. \quad . \quad . \quad . \quad (23).$$

The equations that must be satisfied for all turbine wheels of this class are the equations (16) and (23). The relative efficiency of the wheel is by use of equations (14) and (15) obtained to be:

$$\eta=1-\frac{\mu\sin^2\alpha}{m^2}\cdot\left(\frac{\xi_1}{\xi_2}\right)^2\cdot\left(\frac{B_1}{B_2}\right)^2(1+\cot^2\varphi)\cdot$$
$$\cdot\left\{1+\tfrac{1}{3}\left(\frac{B_2-B_1}{r_2-r_1}\right)^2\cdot\frac{1}{1+\cot^2\alpha}\right\} \quad . \quad . \quad (24).$$

or approximately:

$$\eta=1-\frac{\mu\sin^2\alpha}{m^2}\left(\frac{\xi_1}{\xi_2}\right)^2\cdot\left(\frac{B_1}{B_2}\right)^2(1+\cot^2\varphi) \quad . \quad (24').$$

For turbines where the water discharges under the lowest suface of the water:

$$H=h_1+h_2+h_3$$
$$H=\frac{c_1^2}{2g}-\frac{c_2^2}{2g}+\frac{U_2^2}{2g}-\frac{U_1^2}{2g}-\frac{V_2^2}{2g}+\frac{V_1^2}{2g}+$$
$$+\frac{c_3^2}{2g}-\frac{c_0^2}{2g}$$

according to the equations (17), (19) and (20.). By use of equation (13.) and by assuming $c_3=c_0$ is obtained after some transformations:

$$\left(\frac{c_2}{c}\right)^2=\left(\frac{c_1}{c}\right)^2-1+\left(\frac{U_2}{c}\right)^2-\left(\frac{U_1}{c}\right)^2-$$
$$-\left(\frac{V_2}{c}\right)^2+\left(\frac{V_1}{c}\right)^2$$

By use of equations (2.), (3.), (4.), (7.) and (8.) is obtained:

$$\left(\frac{c_2}{c}\right)^2=\mu-1+\mu\sin^2\alpha\left(\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}\right)^2\cdot$$
$$\cdot m^2(1+\cot^2\gamma)-\mu\sin^2\alpha(1+\cot^2\beta)-$$
$$-\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2m^2+$$
$$+\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2$$

From equation (16.):

$$\frac{\cot\alpha+\cot\beta}{\cot\gamma-\cot\varphi}\cdot m=\cdot\frac{1}{m}\quad\frac{\xi_1}{\xi_2}\quad\frac{B_1}{B_2}$$

and then:

$$\left(\frac{c_2}{c}\right)^2=\mu-1+\mu\sin^2\alpha\cdot\frac{1}{m^2}\cdot\left(\frac{\xi_1}{\xi_2}\right)^2\cdot\left(\frac{B_1}{B_2}\right)^2\cdot$$
$$\cdot(1+\cot^2\gamma)-\mu\sin^2\alpha(1+\cot^2\beta)-$$
$$-\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2\cdot m^2+$$
$$+\mu\sin^2\alpha(\cot\alpha+\cot\beta)^2$$

or after some transformations:

$$\left(\frac{c_2}{c}\right)^2=\mu\sin^2\alpha\left\{\left(\frac{\xi_1}{\xi_2}\right)^2\cdot\left(\frac{B_1}{B_2}\right)^2\cdot\frac{1}{m^2}\cdot\right.$$
$$\cdot(1+\cot^2\gamma)-m^2(\cot\alpha+\cot\beta)^2+$$
$$\left.+2\cot\alpha(\cot\alpha+\cot\beta)-\frac{1}{\mu\sin^2\alpha}\right\}. \quad (25.)$$

From this equation by use of equations (15.) and (16.):

$$\cot\gamma=\frac{\cot^2\varphi+\frac{\xi_2}{\xi_1}\cdot\frac{B_2}{B_1}\cdot\cot\alpha\cdot\cot\varphi+\frac{m^2}{2\mu\sin^2\alpha}\cdot\left(\frac{\xi_2}{\xi_1}\right)^2\cdot\left(\frac{B_2}{B_1}\right)^2}{\cot\varphi+\frac{\xi_2}{\xi_1}\cdot\frac{B_2}{B_1}\cot\alpha}$$
$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad (26.)$$

The equations which must be satisfied for all turbine wheels of this class are then: equations (16.) and (26.). The relative efficiency is obtained from equation (24.).

The less the angle α is, the less is the loss of the efficiency caused by the spread of the water; but this loss is very unimportant if the wheel has such a form as Fig. 4 indicates, and the efficiency of the wheels can be assumed to be independent of the value of the angle α, if it is assumed that the value $\sqrt{\mu}\sin\alpha$ is a constant, that indicates the proportion between the velocities N_1 and c. If the normal velocity (N_1) at the inlet of the wheel is assumed to be $\frac{1}{r}$ of the velocity c, then is the value $\sqrt{\mu}\sin\alpha=\frac{1}{r}$

In the theory the value $\sqrt{\mu}.\sin\alpha$ is used even if $\sin\alpha$ is equal to unity, in order to show that it is a constant.

From equation (24.) it is found that the conditions, which must be satisfied in order to obtain good efficiency, are:

The normal velocity of the water when it enters the wheel ought to have but little value—that is to say that the value $\sqrt{\mu}.\sin\alpha$ ought to be slight.

The value m ought to have a great value—that is to say, that outward flow turbines give the best efficiency.

The value of cot φ ought to be as little as possible.

The first two values have the most influence upon the efficiency. The angle φ has not as much, because the value $1+\cot^2\varphi$ is almost constant for small values of $\cot\varphi$.

ON THE SOURCES OF ENERGY IN NATURE AVAILABLE TO MAN FOR THE PRODUCTION OF MECHANICAL EFFECT.

By SIR WILLIAM THOMSON, F.R.S.

From Papers of the British Association.

During the fifty years' life of the British Association, the advancement of Science, for which it has lived and worked so well, has not been more marked in any department than in one which belongs very decidedly to the Mathematical and Physical Section—the science of Energy. The very name energy, though first used in its present sense by Dr. Thomas Young about the beginning of this century, has only come into use practically after the doctrine which defines it had, during the first half of the British Association's life, been raised from a mere formula of mathematical dynamics to the position it now holds—as a principle pervading all nature and guiding the investigator in every field of science.

A little article communicated to the Royal Society of Edinburgh, a short time before the commencement of the epoch of energy, under the title "On the Sources Available to Man for the Production of Mechanical Effect," contained the following:

"Men can obtain mechanical effect for their own purposes by working mechanically themselves, and directing other animals to work for them, or by using natural heat, the gravitation of descending solid masses, the natural motions of water and air, and the heat, or galvanic currents, or other mechanical effects produced by chemical combination, but in no other way at present known. Hence the stores from which mechanical effect may be drawn by man belong to one or other of the following classes:

"I. The food of animals.

"II. Natural heat.

"III. Solid matter found in elevated positions.

"IV. The natural motions of water and air.

"V. Natural combustibles (as wood, coal, coal-gas, oils, marsh-gas, diamond, native sulphur, native metals, meteoric iron).

"VI. Artificial combustibles (as smelted or electrically-deposited metals, hydrogen, phosphorus).

"In the present communication, known facts in natural history and physical science, with reference to the sources from which these stores have derived their mechanical energies, are adduced to establish the following general conclusions:

"1. *Heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man.* From it is derived the whole mechanical effect obtained by means of animals working, water-wheels worked by rivers, steam-engines, galvanic engines, wind-mills, and the sails of ships.

"2. The motions of the earth, moon, and sun, and their mutual attractions, constitute an important source of available mechanical effect. From them all, but chiefly no doubt from the earth's

motion of rotation, is derived the mechanical effect of water-wheels driven by the tides.

"3. The other known sources of mechanical effect available to man are either terrestrial—that is, belonging to the earth, and available without the influence of any external body; or meteoric—that is, belonging to bodies deposited on the earth from external space. The terrestrial sources, including mountain quarries and mines, the heat of hot springs, and the combustion of native sulphur, perhaps also the combustion of inorganic native combustibles, are actually used; but the mechanical effect obtained from them is very inconsiderable, compared with that which is obtained from sources belonging to the two classes mentioned above. Meteoric sources, including only the heat of newly-fallen meteoric bodies, and the combustion of meteoric iron, need not be reckoned among those available to man for practical purposes."

Thus we may summarize the natural sources of energy as Tides, Food, Fuel, Wind and Rain.

Among the practical sources of energy thus exhaustively enumerated, there is only one not derived from sun-heat, that is the tides. Consider it first. I have called it *practical*, because tide mills exist, but the places where they can work usefully are very rare, and the whole amount of work actually done by them is a drop to the ocean of work done by other motors. A tide of two meters' rise and fall—if we imagine it utilized to the utmost by means of ideal water wheels doing, with perfect economy, the whole work of filling and emptying a dock basin in infinitely short times, at the moments of high and low water—would give just one meter-ton per square meter of area. This work done four times in the twenty-four hours, amounts to 1.1620th of the work of a horse power. Parenthetically, in explanation, I may say that the French metrical equivalent (to which in all scientific and practical measurements we are irresistibly drawn, notwithstanding a dense barrier of insular prejudice most detrimental to the islanders),—the French metrical equivalent of James Watt's "horse power" of 550 foot-pounds per second, or 33,000 foot-pounds per minute, or nearly 2,000,000 foot-pounds per hour, is 75 meter-kilogrammes per second, or $4\frac{1}{2}$ meter-tons per minute, or 270 meter-tons per hour. The French ton of 1000 kilos, used in this reckoning, is 0.984 of the British ton.

Returning to the question of utilizing tidal energy, we find a dock area of 162,000 square meters (which is little more than 400 meters square) required for 100 horse-power. This, considering the vast costliness of dock construction, is obviously prohibitory of every scheme for economizing tidal energy by means of artificial dock basins, however near to the ideal perfection might be the realized tide-mill, and however convenient and non-wasteful the accumulator—whether Faure's electric accumulator, or other accumulators of energy hitherto invented, or to be invented,—which might be used to store up the energy yielded by the tide mill during its short harvests about the times of high and low water, and to give it out when wanted at other times of six hours. There may, however, be a dozen places possible in the world where it could be advantageous to build a sea-wall across the mouth of a natural basin or estuary, and to utilize the tidal energy of filling it and emptying it by means of sluices and water-wheels. But if *so* much could be done, it would in many cases take only a little more to keep the water out altogether, and make fertile land of the whole basin. Thus we are led up to the interesting economical question, whether is 40 acres (the British *agricultural* measure for the area of 162,000 square meters) or 100 horse power more valuable? The annual cost of 100 horse power night and day for 365 days of the year, obtained through steam from coals, may be about ten times the rental of forty acres, at £2 or £3 per acre. But the value of land is essentially much more than its rental, and the rental of land is apt to be much more than £2 or £3 per acre in places where 100 horse-power could be taken with advantage from coal through steam. Thus the question remains unsolved, with the possibility that in one place the answer may be *one hundred horse power*, and in another *forty acres*. But, indeed, the question is hardly worth answering, considering the rarity of the cases, if they exist at all, where embankments for the utilization of tidal energy are practicable.

Turning now to sources of energy derived from sun-heat, let us take wind first. When we look at the register of British shipping, and see 40,000 vessels, of which about 10,000 are steamers and 30,000 sailing ships, and when we think how vast an absolute amount of horse power is developed by the engines of those steamers, and how considerable a proportion it forms of the whole horse power taken from coal annually in the whole world at the present time, and when we consider the sailing ships of other nations, which must be reckoned in the account, and throw in the little item of wind-mills, we find that, even in the present days of steam ascendancy old-fashioned wind still supplies a large part of all the energy used by man. But however much we may regret the time when Hood's young lady, visiting the fens of Lincolnshire, at Christmas, and writing to her dearest friend in London (both sixty years old if they are now alive), describes the delight of sitting in a bower and looking over the wintry plain, not desolate, because "wind-mills lend revolving animation to the scene," we cannot shut our eyes to the fact of a lamentable decadence of wind-power. Is this decadence permanent, or may we hope that it is only temporary? The subterranean coal stores of the world are becoming exhausted surely, and not slowly, and the price of coal is upward bound—upward bound on the whole, though no doubt it will have ups and downs in the future as it has had in the past, and as must be the case in respect to every marketable commodity. When the coal is all burned, or long before it is all burned—when there is so little of it left, and the coal mines from which that little is to be excavated are so distant and deep and hot that its price to the consumer is greatly higher than at present, it is most probable that wind-mills or wind-motors in some form, will again be in the ascendant, and that wind will do man's mechanical work on land at least, in proportion comparable to its present doing of work at sea.

Even now, it is not utterly chimerical to think of wind superseding coal in some places for a very important part of its present duty—that of giving light. Indeed, now that we have dynamos and Faure's accumulator, the little want to let the thing be done is cheap wind-mills. A Faure cell containing 20 kilos. of lead and minium charged and employed to excite incandescent vacuum-lamps has a light-giving capacity of 60 candle hours (I have found considerably more in experiments made by myself, but I take sixty as a safe estimate). The charging may be done uninjuriously, and with good dynamical economy in any time from six to twelve hours or more. The drawing off of the charge for use may be done safely, but somewhat wastefully, in two hours, and very economically in any time of from five hours to a week, or more. Calms do not last often longer than three or four days at a time. Suppose, then, that a five-days storage capacity suffices:—(There may be a little steam engine ready to set to work at any time after a four days' calm, or the user of the light may have a few candles or oil lamps in reserve and be satisfied with them when the wind fails for more than five days.) One of the 20-kilo. cells charged when the wind-mill works, for five or six hours at any time and left with its 60 candle-hours' capacity to be used six hours a day for five days, gives a 2-candle light. Thus thirty-two such accumulator cells soused would give as much light as four burners of London 16-candle gas. The probable cost of dynamo and accumulator does not seem fatal to the plan, if the wind mill could be had for something comparable with the prime cost of a steam engine, capable of working at the same horse power as the wind-mill when in good action. But wind-mills as hitherto made are very costly machines; and it does not seem probable that without inventions, not yet made, wind can be economically used to give light in any considerable class of cases, or to put energy into store for other kinds of work.

Consider, lastly, rain power. When it is to be had in places where power is wanted for mills and factories of any kind, water power is thoroughly appreciated. From time immemorial, water-power motors have been made in large variety for utilizing rain power in the various conditions in which it is presented, whether in rapidly-flowing rivers in natural waterfalls, or stored at heights in natural lakes or artificial reservoirs. Improvements and fresh inventions of

machines of this class still go on; and some of the finest principles of mathematical hydrodynamics have, in the lifetime of the British Association, and, to a considerable degree with its assistance, been put in requisition for perfecting the theory of hydraulic mechanism and extending its practical applications.

A first question occurs: Are we necessarily limited to such natural sources of water power as are supplied by rain falling on hill country, or may we look to the collection of rain water in tanks, placed artificially at sufficient heights over flat country, to supply motive power economically by driving water wheels? To answer it: Suppose a height of 100 meters, which is very large for any practicable building, or for columns erected to support tanks; and suppose the annual rainfall to be three-quarters of a meter (30 inches). The annual yield of energy would be 75 meter-tons per square meter of the tank. Now one horse-power for 365 times 24 hours is 236,500 foot-tons; and therefore, dividing this by 75, we find 3153 sq. meters as the area of our supposed tank required for a continuous supply of one horse power. The prime cost of any such structure, not to speak of the value of the land which it would cover, is utterly prohibitory of any such plan for utilizing the motive power of rain. We may or may not look forward hopefully to the time when windmills will again "lend revolving animation" to a dull flat country; but we certainly need not be afraid that the scene will be marred by forests of iron columns taking the place of natural trees, and gigantic tanks overshadowing the fields and blackening the horizon.

To use rain power economically on any considerable scale we must look to the natural drainage of hill country, and take the water where we find it, either actually falling or stored up and ready to fall, when a short artificial channel or pipe can be provided for it at moderate cost. The expense of aqueducts, or of underground water pipes, to carry water to any great distance—any distance of more than a few miles or of a few hundred yards—is much too great for economy when the yield to be provided for is *power;* and such works can only be undertaken when the *water itself* is what is wanted. Incidentally, in connection with the water supply of towns, some part of the energy due to the head at which it is supplied may be used for power. There are, however, but few cases (I know of none except Greenock) in which the energy to spare and above that devoted to bringing the water to where it is wanted, and causing it to flow fast enough for convenience at every opened tap in every house or factory, is enough to make it worth while to make arrangements for letting the water power be used without wasting the water substance. The cases in which water power is taken from a town supply are generally very small, such as working the bellows of an organ, or "hair-brushing by machinery," and involve simply throwing away the used water. The cost of energy thus obtained must be something enormous in proportion to the actual quantity of the energy, and it is only the smallness of the quantity that allows the convenience of having it when wanted at any moment to be so dearly bought.

For anything of great work by rain-power, the water-wheels must be in the place where the water supply with natural fall is found. Such places are generally far from great towns; and the time has not yet come when great towns grow by natural selection beside waterfalls for power, as they grow beside navigable rivers, for shipping. Thus hitherto the use of water power has been confined chiefly to isolated factories, which can be conveniently placed and economically worked in the neighborhood of natural waterfalls. But the splendid suggestion made about three years ago by Mr. Siemens, in his presidential address to the institution of Mechanical Engineers, that the power of Niagara might be utilized, by transmitting it electrically to great distances, has given quite a fresh departure for design in respect to economy of rain-power. From the time of Joule's experimental electro-magnetic engines, developing 90 per cent. of the energy of a Voltaic battery in the form of weights raised, and the theory of the electro-magnetic transmission of energy completed thirty years ago on the foundation afforded by the train of experimental and theoretical investigations, by which he established his dynamical equivalent of heat in mechanical,

electric, electro-chemical, chemical, electro-magnetic, and thermo-electric phenomena, it had been known that potential energy from any available source can be transmitted electro-magnetically by means of an electric current through a wire, and directed to raise weights at a distance, with ulimitedly perfect economy. The first large-scale practical application of electro-magnetic machines was proposed by Holmes in 1854, to produce the electric light for lighthouses, and persevered in by him till he proved the availability of his machine, to the satisfaction of the Trinity House and the delight of Faraday, in trials at Blackwall in April, 1857, and it was applied to light the South Foreland lighthouse on December 8, 1858. This gave the impulse to invention; by which the electro-magnetic machine has been brought from the physical laboratory into the province of engineering, and has sent back to the realm of pure science a beautiful discovery—that of the fundamental principle of the dynamo, made triply and independently, and as nearly as may be simultaneously, in 1867, by Dr. Werner Siemens, Mr. S. A. Varley, and Sir Charles Wheatstone; a discovery which constitutes an electro-magnetic analogue to the fundamental electrostatic principle of Nicholson's revolving doubler, resuscitated by Mr. C. F. Varley in his instrument "for generating electricity;" patented in 1860; and by Holtz in his celebrated electric machine; and by myself in my "replenisher" for multiplying and maintaining charges in Leyden jars for heterostatic electrometers, and in the electrifier for the siphon of my recorder for submarine cables.

The dynamos of Gramme and Siemens, invented and made in the course of these fourteen years since the discovery of the fundamental principle, give now a ready means of realizing economically on a large scale, for many important practical applications, the old thermo-dynamics of Joule in electro-magnetism; and, what particularly concerns us now in connection with my present subject, they make it possible to transmit electro-magnetically the work of waterfalls through long insulated conducting wires, and use it at distances of fifties or hundreds of miles from the source, with excellent economy—better economy, indeed, in respect to proportion of energy used to energy dissipated than almost anything known in ordinary mechanics and hydraulics for distances of hundreds of yards instead of hundreds of miles.

In answer to questions put to me in May, 1879, by the Parliamentary Committee on Electric Lighting, I gave a formula for calculating the amount of energy transmitted, and the amount dissipated by being converted into heat on the way, through an insulated copper conductor of any length, with any given electro-motive force applied to produce the current. Taking Niagara as example, and with the idea of bringing its energy usefully to Montreal, Boston, New York, and Philadelphia, I calculated the formula for the distance of 300 British statute miles (which is greater than the distance of any of those four cities from Niagara, and is the radius of a circle covering a large and very important part of the United States and British North America), I found almost to my surprise that, even with so great a distance to be provided for, the conditions are thoroughly practicable with good economy, all aspects of the case carefully considered. The formula itself will be the subject of a technical communication to Section A in the course of the meeting on which we are now entering. I therefore at present restrict myself to a slight statement of results.

1. Apply dynamos driven by Niagara to produce a difference of potential of 80,000 volts between a good earth connection and the near end of a solid copper wire of half an inch (1.27 centimeter) diameter, and 300 statute miles (483 kilometers) length.

2. Let resistance by driven dynamos doing work, or by electric lights, or as I can now say, by a Faure battery taking in a charge, be applied to keep the remote end at a potential differing by 64,000 volts from a good earth-plate there.

3. The result will be a current of 240 webers through the wire taking energy from the Niagara end at the rate of 26,250 horse power, losing 5250 (or 20 per cent.) of this by the generation and dissipation of heat through the conductor and 21,000 horse-power (or 80 per cent. of the whole) on the recipients at the far end.

4. The elevation of temperature above the surrounding atmosphere, to allow the heat generated in it to escape by radiation and be carried away by convection is only about 20° Centigrade; the wire being hung freely exposed to air like an ordinary telegraph wire supported on posts.

5. The striking distance between flat metallic surfaces with difference of potentials of 80,000 volts (or 75,000 Daniell's) is (Thompson's "Electrostatics and Magnetism." § 340) only 18 millimeters, and therefore there is no difficulty about the insulation.

6. The cost of the copper wire, reckoned at 8d. per lb., is £37.000, the interest on which at 5 per cent is £1900 a year. If 5250 horse power at the Niagara end costs more than £1900 a year, it would be better economy to put more copper into the conductor; if less, less. I say no more on this point at present, as the economy of copper for electric conduction will be the subject of a special communication to the Section.

I shall only say, in conclusion, that one great difficulty in the way of economizing the electrical transmitting power to great distances, or even to moderate distances of a few kilos., is now over come by Faure's splendid invention. High potential—as Siemens, I believe, first pointed out—is the essential for good dynamical economy in the electric transmission of power. But what are we to do with 80,000 volts when we have them at the civilized end of the wire? Imagine a domestic servant going to dust an electric lamp with 80,000 volts on one of its metals? Nothing above 200 volts ought on any account ever to be admitted into a house or ship or other place where safeguards against accident cannot be made absolutely and forever trustworthy against all possibility of accident. In an electric workshop 80,000 volts is no more dangerous than a circular saw. Till I learned Faure's invention I could but think of step-down dynamos, at a main receiving station to take energy direct from the electric main with its 80,000 volts, and supply it by secondary 200-volt dynamos or 100-volt dynamos, through proper distributing wires, to the houses and factories and shops where it is to be used for electric lighting, and sewing machines, and lathes, and lifts, or whatever other mechanism wants driving power. Now the thing is to be done much more economically, I hope, and certainly with much greater simplicity and regularity, by keeping a Faure battery of 40,000 cells always being charged direct from the electric main, and applying a methodical system of removing sets of 50, and placing them on the town-supply circuits, while other sets of 50 are being regularly introduced into the great battery that is being charged, so as to keep its number always within 50 of the proper number, which would be about 40,000 if the potential at the emitting end of the main is 80,000 volts.

ELECTRIC LIGHTING AT THE PARIS EXHIBITION.

By WILLIAM HENRY PREECE, F.R.S.

From the "Journal of the Society of Arts."

THE recent International Exhibition of Electricity in Paris makes an epoch in the history of the practical applications of that science to Arts, Manufactures, and Commerce. I purpose now to refer only to its application to artificial illumination; but there are many other branches fully deserving examination and discussion by this Society. It was, however, as an exhibition of electric lighting that it was principally attractive, and those who saw it for the first time will never forget the vivid impression that the great blaze of splendor produced upon their minds on entering the building. There never can be anything like it again, for as wisdom grows with experience, so no manager of any future Exhibition is likely to repeat that terrific *mélange* of lights that flooded the interior of the Palais de l'Industrie with great brilliancy, but with an impracticable and impossible means of comparing and judging the relative merits of different systems.

For instance, at the forthcoming Exhibition at the Crystal Palace, the building—splendidly adapted for the purpose—will be divided into sections, each sec-

tion being lit by one, and only one system. But at Paris, Pelion was piled upon Ossa; the British Section, for instance, received rays from at least a dozen different sources. To estimate the value of a Siemens lamp you had to eliminate the disturbing influence of a blazing Crompton; and to admire the star-like Jaspar arc, you had to run the gauntlet of a flock of Swans. The fretful Jamin, or the fitful Jablochkoff, was masked by the steady Gülcher or the brilliant Serrin. In the galleries, however, it was different. Here, different *salles* were illuminated by different systems; a small theatre was lit by the Werderman lamp, and a picture gallery most effectively shown up by the *Lampe Soleil;* a buffet was softly and brightly lit up with the Swan lamp, while Mr. Edison's numerous exhibits, in his own *salons*, were as visible by night as by day, thanks to his own beautiful lamp.

It is not my intention to examine, *seriatim*, the various machines, lamps, and modes of illumination shown. With most of them, you are already familiar. But I purpose to select what appeared to me to be novelties, and what seemed worthy of being brought to your notice, as steps in advance.

On the night of August 29th, there were in operation 277 arc lamps, 116 candles, 44 arc incandescent lamps, 1,500 incandescent lamps, or a total of 1,837 electric lights in all, at the Paris Exhibition. Towards the end of the period during which the show was opened, this number was very largely increased, and I have little doubt that the number reached 2,500 in the beginning of November. Now this army of lamps required power to convert the energy stored up in coal into energy of motion; dynamo-machines to convert the energy of motion into electrical energy; conductors to transport this electric energy to the point to be illuminated; lamps to convert the electric energy into energy of heat, and therefore of light.

The exhibition of engines and machinery was very extensive, although our English manufacturers failed to do what they might have done had they thought as highly of the Exhibition at first as they did afterwards. Many of our manufacturers were conspicuous by their absence. The only extensive display was by Messrs. Robey & Co., of Lincoln, who showed eight of their well-known engines, with a total power of 250 horses, and I have every reason to believe that their success has amply repaid them for their enterprise. Mr. Brotherhood made a small show of his well-known three-cylinder engines and Messrs. Wallis & Stevens, of Basingstoke, sent one of their semi-fixed steam-engines, with their pretty and effective governor for adjusting the speed while in motion—uniformity in speed being an essential criterion of an electric-light engine. The foreigners, for a wonder, far outshone the British in the magnitude of their displays.

One of the most valuable exhibits was made by Messrs. Thomson, Sterne & Co., who showed a new gas engine on a new principle, which attracted a great deal of attention. Gas is destined to play a most important *rôle* in the future of electric lighting. Its function is that of a heat-generator. The energy of the coal exists in gas in a form which can develop more light, when converted into the form of electricity, by the current, than in the form of heat by combustion. Gas engines have a very high theoretical efficiency, and they are free from the dangers of boilers, the neglect of stokers, or the waste of energy in chimneys.

Gas engines on the "Otto" principle, from half horse power to 50 horse power, were very extensively exhibited by France, but the machine of Thomson, Sterne & Co. (Clerk's patent) excelled them all in lightness, compactness, regularity, and safety. One of these engines may now be seen at work at the Smoke Abatement Exhibition at South Kensington, and several have been ordered for private houses. As an adjunct to the gas engine, Mr. Dowson exhibited an interesting and valuable process of making cheap gas for motor purposes. Prof. Ayrton reported that in a series of trials made with a 3½ H. P. (nominal) "Otto" engine, driven by the Dowson gas, one H. P. (indicated) was obtained per hour by the consumption of gas derived from 1.46 lbs. of coal. For larger engines he anticipated a consumption of only 1.2 lbs. per indicated horse power per hour. You will have a paper during the Session by Mr. Dowson himself, describing his mode of manufacture. When perhaps 6 lbs. of coal per horse power per hour are

consumed in the present electric-light steam-engines, you can form some idea of the economy to be effected by cheap gas.

Dynamo-machines — machines which convert the energy of motion into electrical energy, through the medium of magnetism—were exhibited in abundance, of all kinds and forms, from the original apparatus of Faraday, made with his own hands, to Mr. Edison's latest development of this wonderful source of electric currents. There are two kinds of machines—the one producing currents from fixed and permanent steel magnets, the other from electro-magnets, excited by the currents which they themselves generate. Each kind is also sub-divided into two others, in one of which continuous currents are produced, flowing in one direction, called the *continuous current machine;* and in the other alternate currents, called the *alternate current machine*, where the current rapidly reverses and changes its direction. The production of currents by these machines is due to the simple fact discovered by Faraday, that if a conductor, such as a copper wire, be moved rapidly through a magnetized space, or a magnetic field, as it is called, this conductor is electrified so that, if its two ends be connected, a current flows. The intensity of this current depends, first, on the intensity of the magnetism present, on the velocity with which the conductor moves through the field, and on the direction with which it cuts the lines of magnetic force which permeate the magnetic field. The magneto-electric kind—the manufacture and invention of M. de Meritens—are very much approved of by our Trinity House for lighthouse purposes, and a very fine display of them was made by M. de Meritens, who seemed to live in the Exhibition, for he was always there, and who never seemed to tire of giving his clear and able descriptions. He exhibited alternate and continuous current machines, and he richly deserved the gold medal that was accorded to him. The exhibition of dynamo-machines was rendered very interesting by the exhibition of an early machine of Elias, of Haarlem, of 1842, and of Pacinotti's machines of 1861. The former was shown in the Dutch Section, and the latter in the Italian. Here we have the germs of all the present machines, and by whatever name a machine may be known, it can be traced back to these original types. The Pacinotti apparatus has been very greatly improved by Gramme, and by Siemens—forms well known to every one —but it has received its greatest development in the Edison machine, which was one of the wonders of the Exhibition. As this was one of the greatest novelties, I must briefly describe it. In the first place, I must point out that the machine is larger than any one that has ever been made before. It weighs, with engine and bed plates, 20 tons, and it can produce a current of electricity of nearly 900 amperes.* As the largest machine of the Gramme type weighs scarcely one ton, and produces a current of but 93 amperes, the difference becomes striking. Now, Mr. Edison has struck out three new paths, first—in the bulk and form of his electro-magnets, second—in the size and construction of his armature, and third—in the low resistance of his revolving coil. By the first, he secures an intense and concentrated magnetic field, by the second he secures a high cutting velocity for the moving conductor through this field, and by the third, he secures a very powerful current to be distributed among a great number of lamps with the least possible waste of energy. The long and bulky coils, 8 feet long, which constitute his electro-magnet, have excited the surprise of many electricians, but there is no doubt that he has arrived at this form after many careful practical experiments, supported by the mathematical investigations of Professor Rowland—a very high authority—and that the result is to obtain an intense field in a large space, with the least absorption of electrical energy in the coils. With 350 revolutions per minute he is able to produce an electro-motive force of 110 volts, which an ordinary Gramme machine can only attain with over 1,000 revolutions per minute. His field-magnets are wound with copper wire, which have a resistance of 30 ohms, and which are connected as a shunt to the main circuit, as was originally done by Wheatstone, and is now followed by Dr. Siemens and Sir William Thomson. The armature is not wound with wire, but is constructed with solid bars of copper $\frac{3}{4}$ in. by $\frac{1}{2}$ in. section, and

*The largest Brush machine weighs two tons, and absorbs 40-horse power.

3¼ feet long, which are well insulated from each other, and are most ingeniously connected at their ends by copper discs, so that all the bars, of which there are 138, form one continuous circuit, whose total resistance is only 0.008 of an ohm. The diameter of the armature is 28 inches. The core of the armature is made up of 1,700 thin iron discs insulated from each other by paper, and well clamped into a solid mass by bolts. This is done to avoid the heating effects due to so-called Foucault currents induced in the metal and absorbing or wasting energy. The iron core of the armature becomes thus magnetized, and it concentrates the field to the space through which the conductor moves, as is done in Siemens' and other machines.

There are two great troubles in existing machines, want of uniformity in their motion and the slipping of belts. The former is met by governors, and the latter by direct gearing. Steadiness of motion is most essential, otherwise we have that painful throbbing of the light that is so irritating to the eyes. Mr. Edison connects his armature direct to his steam motor, which is a high-pressure engine of the Allen-Porter type, governed by an ingenious centrifugal regulator, and ro tating very uniformly at 350 revolutions per minute, without any multiplying gear whatever. When the machine is giving out its maximum commercial effect it absorbes 125-horse power, the external resistance should be 16 times that of the armature, the electro-motive force 110 volts, and the current consequently 860 amperes. It is not safe to exceed this limit, for the armature then becomes unduly heated. A special blower is added to direct cold air on the armature to keep down the heat, when the work of the machine approaches its limit. The brush is a special feature of the machine. The absence of sparking was very striking. Mr. Edison coats his brush and commutator with an amalgam of copper, which diminishes the electrical resistance of contact, reduces the heat, and prevents sparking.

Those who are interested in this machine—and every one should be, for it is a decided step in advance—will soon have an opportunity of seeing it at work at 57, High Holborn.

There was a very interesting form of Gramme machine shown, which was maintained at a velocity of 2,400 revolutions per minute, and was said to generate an electromotive force of 2,000 volts. It maintained 60 Jamin candles alight. But one of the best and most compact forms of Gramme was that shown by the British Electric Light Company, designed by their engineer, and made for them by Messrs. Emerson, in Stockport.

The display of lamps was the display of the building. There were very few novelties among arc lamps. An arc lamp consists of two sticks or rods of carbon, which are kept apart a small fraction of an inch while the current flows through them, but which comes together when the current ceases. Across the interval separating them there is a steady flow of electricity, accompanied by a slow consumption of the carbon of each rod. This flow of electricity produces high temperature, and intense incandescence and combustion of the carbon particles. This is the arc. One lamp differs from another only in the way in which the carbons are moved forward as they consume, so as to maintain the resistance equal and the light steady. Among arc lamps, that which signaled itself out among all its compeers, for steadiness and brilliancy, was the Jaspar lamp, exhibited in the Belgian Section; but it had the disadvantage of absorbing all the energy of one machine. Among those that admitted of having a number on one section, perhaps the simplest in its construction was the Gülcher, exhibited in the Austrian Section; but the most effective and original was the "Pilsen" lamp, the invention of Messrs. Piette & Krisik. It is called the "Pilsen" lamp, from the place of its birth, and from the want of euphoniousness in the names of its inventors. It was exhibited in the Austrian Section, and also in the British Section, by Mr. Fyfe. The carbons are kept apart by a sucking coil when the current flows; they are regulated by a second sucking coil worked on a shunt. The peculiarity of the lamp consists principally in the shape of the core that controls the carbon—it is wedge-shaped at each end; in action is wonderfully regular, and almost perfect. Six lamps were worked in one circuit by a Schuckert machine.

The *Lampe Soleil*, which holds an intermediate position between arc and in-

candescent lamps, made a very effective display in the picture gallery, where there were 20 lamps in 10 lanterns. It is to be seen in London lighting up the Panorama in Westminster. It is a fixed, steady, durable lamp, giving a soft yellowish light, which is due to the fact that the arc maintains in incandescence a highly refractory substance like marble, between the two ends at the carbon. It is a very simple lamp, for it involves no mechanism whatever; but it is said to absorb a great deal of power, though I have seen no reliable figures of its performance. Its consumption of carbon is remarkably small. It is worked by an alternate current machine, which, like most of these machines, made a most unpleasant hum.

Carrè made a very fine display of carbons for arc lights, for the manufacture of which he is so famous, in which the regularity of form, of structure, and of composition, is said to be absolute; but it is very questionable whether this is really the case in practice, for the irregularity of the arc lights is chiefly due to impurities and irregularities in the carbon. Moreover, the very vast discrepancies that are found in the photometric measurements of the same lamp at different times, or by different persons, may be due to the irregularities in the structure of the artificial carbon rods.

No one can deny that the Jablockhoff candle has done good service in the cause of electric lighting; but I am afraid that the Exhibition in Paris has sounded the knell of all forms of candle, as well as those of the Werderman type. The rising favorite is the incandescent lamp, pure and simple. The display made by Mr. Swan in the buffet, in the Congress Hall, and in the Pavilion at the Post-office, was brillant and effective. The light was soft, uniform, and yellow. The incandescent light is totally free from those bright rays that are so injurious to the eyes, so uncomplimentary to the complexion, and so irritating to the worker, if they are accompanied with the least unsteadiness. It is so readily under control; it requires no skilled labor to replace it or attend to it; it can be fixed anywhere; it can be worked into the fixtures and decorations of a room, and it does not damage them, as gas and oil do. Incandescent lamps can be worked by either continuous or alternate current machines. In fact, the chief lesson of the Paris Exhibition is this, that the arc light is specially suited for external illumination, and that incandescent lamps are eminently adapted for internal and for domestic illumination. This lesson has been carried into practice at the Savoy Theatre, where nothing can be more effective or more efficient than the illumination of the auditorium. One can breathe pure air, feel cool, and can sit out a play without incurring a headache. There were several incandescent lamps shown at Paris besides those of Mr. Swan, notably those of Maxim and Lane-Fox; but that which possessed the greatest novelty, and was decidedly the most efficient, was that of Mr. Edison. The distinctive character of the Edison lamp is the remarkable uniformity of its texture and light-giving power. The lamp consists of a fine filament of carbon inserted as a part of the electric circuit in a glass globe, which has been exhausted of air to the utmost limit of workshop skill. A fine, uniform quality of Japanese bamboo has been selected as that which gives the finest filament for carbonizing. The bamboo is cut by special machinery into the required dimensions, and inserted in a mould, which is placed in a furnace, and raised to a very high temperature, and from which the filament comes out shaped and carbonized. Naturally grown vegetable fiber has been found to give a more uniform texture than any artificially-formed carbon. The ends are cut flat, and squeezed inside copper clamps, which are then welded together by electro-plating. The copper clamps being soldered to platinum leads that are sealed through the glass, and are connected to the conductors. Perfect sealing is obtained by flattening the mass of the tube, through which the fine platinum wires pass into a solid bar, so as to well fuse the wires and glass together. It is a fortunate thing for the permanence of the incandescent lamp that the co-efficient of expansion, due to heat, of glass and platinum is practically the same.

The normal lamp consists of a filament 6 inches long, which gives a resistance of 240 ohms when cold, and, when permeated by a current of 0.8 ampere, gives a light equivalent to 16 sperm candles.

The half lamp is constructed with a carbon filament of just half the length and half the resistance, and gives eight candles. Other lamps are made with two and four horse-shoe filaments, so as to increase the light-giving power. The features of carbon, which render it so highly adapted for incandescence, are its electrical resistance, its high refractory character, and its stability. The illumination of a filament and its durability are functions of the current that passes; the more intense the current the higher the temperature, and therefore the brighter the light and the shorter its life. At a temperature of about 1,000° carbon becomes red, at 2,000° it is white, and the higher the temperature the whiter it gets, until it fuses. A current of 0.8 of an ampere maintains an Edison filament at about 2,000°, when it gives a light of 16 candles, and it lasts on an average 1,000 hours. A stronger current will give a much better light, but the carbon will not last so long. If it were possible to find a form of carbon, or any other material, which would be so refractory that we could transmit through it much stronger currents, the incandescent lamp would rival the arc lamp in brilliancy and power.

The destruction of the carbon filament in incandescent lamps is due to what is called the Crookes' effect, a very slow transference of carbon, in a molecular shower, from the one heel to the other heel of the horseshoe, until a breakdown takes place at the former point. The better the vacuum the slower this effect. Alternate current machines are said to lengthen the life of the carbons, by equalizing the distribution of molecules on each heel, but they do so at the expense of efficiency.

Many devices were shown for measuring the quantity of electricity consumed in any place by electric lamps; but that adopted by Mr. Edison is sufficiently simple and accurate for all practical purposes. A glass cell contains two copper plates immersed in a solution of sulphate of copper. A definite proportion (0.001) of the current that passes through the house passes also through this cell, and removes copper from one plate and deposits copper on one plate. The weight of copper deposited is an exact measure of the current used. There are two such cells—the one in charge of the consumer and the other of the supplier. They thus check each other.

Various plans were shown in different parts of the Exhibition to diffuse the light, but the most effective was that in *Salle* 15, where a Jaspar lamp filled the room with a shadowless light, by throwing a light on to a white screen above the lamp, whence it was scattered. The lamp itself was invisible. This plan is not novel. It was suggested by the Duke of Sutherland, and has been adopted by Mr. Schwendler in India.

The proper distribution of light is a problem that remains to be solved. It is argued that an arc is so much superior to an incandescent light, that one-horse power in the former gives you ten times more light than in the latter. This is true; but, on the other hand, to obtain a subdued light sufficient for your purpose, you must either put the arc lamp far away or tone it down by shades, and therefore waste it; whereas an incandescent lamp can be toned down, by regulating the current, to any color you like, and it can be fixed just where it is wanted. One-horse power will give you 1,500 candles in an arc, and only 160 candles in 10 incandescent lamps; but these 10 lamps can be so distributed about your space to be lit, as to illuminate your surface or objects with a better light than the arc.

Curiously enough nothing whatever was done in Paris to improve the illumination of streets. The Avenue de l'Opera, the first street practically lighted by electricity, still remains as it was in 1878; but prior to the opening of the Exhibition, a portion of the Boulevard des Italiens was lit up by four De Mersanne lamps, suspended high up, at wide intervals, over the center of the road. The effect was very fine, but the lamps were very bad. This is the true way of illuminating streets, and it is to be regretted that such an experiment is not tried in London. Street illumination in England by electricity up to the present time is, as a rule, a questionable success.

The question remains for discussion: Has the electric light been brought within the region of practical domestics? I have no hesitation in saying that it has; but whether it can be brought into economical contrast with gas, experience

alone will show. Several houses are already illuminated by its agency; others are in hand, my own amongst the number; and when we next meet to consider this subject, I may be able to answer the question with actual facts.

One word as regards the danger of electric lighting. There is no use blinking our eyes to the fact that electricity can be a dangerous servant in the hands of the careless and ignorant; in the hands of the skilled it has less danger than gas, or even oil. The installation of the wires must be controlled by experience and knowledge. I have more than once called attention to this fact, and my warnings have been received with abuse; but in Paris there were no less than five incipient fires, from the wires coming in contact with each other, in the Exhibition building. The *Times* correspondent in Vienna implies that the frightful disaster to the Ring Theatre was due to this cause. The instances in New York are so numerous that the Board of Fire underwriters have issued the following rules:—

"1. Wires to have 50 per cent. excess of conductivity above the amount calculated as necessary for the number of lights to be supplied by the wire.

"2. Wires to be thoroughly insulated and doubly coated with some approved material.

"3. All wires to be securely fastened by some approved non-conducting fastening, and to be placed at least $2\frac{1}{2}$ inches for incandescent light, and 8 inches for arc lights, from each other, and 8 inches from all other wires and from all metal or other conducting substance, and to be placed in a manner to be thoroughly and easily inspected by surveyors. When it becomes necessary to carry wires through partitions and floors, they must be secured against contact with metal or other conducting substance in a manner approved by the inspector of the Board.

"4. All arc lights must be protected by glass globes enclosed at the bottom, to effectually prevent sparks or particles of the carbons from falling from the lamps; and in show windows, mills, and other places where there are materials of an inflammable nature, chimneys with spark arresters shall be placed at the top of the globe. Open lights positively prohibited. The conducting framework of chandeliers must be insulated and covered the same as wires.

"5. Where electricity is conducted into a building (from sources other than the building in which it is used) a shut-off must be placed at the point of entrance to each building, and the supply turned off when the lights are not in use. Applications for permission to use electric lights must be accompanied with a statement of the number and kind of lamps to be used, the estimate of some known electrician of the quantity of electricity required, and a sample of the wire (at least three feet in length) to be used, with a certificate of said electrician of the carrying capacity of said wire. The applications should also state where the electricity is to be generated, whether the connection will have metallic or ground circuit, and, as far as possible, give full details of the manner in which it is proposed to equip the building."

These rules are very simple, and are necessarily carried out by every qualified electrician, but an additional security is obtained by Mr. Edison, by inserting in every branch wire a "safety catch," which is a short piece of lead wire that instantly melts if the strength of the current exceeds a certain value, and thus ruptures the circuit, stopping the flow of electricity, and producing safety.

The completeness of Mr. Edison's exhibit was certainly the most noteworthy object in the exhibition. Nothing seems to have been forgotten, no detail missed. There we saw not only the boilers, engine, and dynamo machine, but the pipes to contain the conductors; the conductors themselves, heavy and massive, for Mr. Edison recognizes the waste of energy that must occur in small conductors, the insulation, the fixtures, the brackets, the safety catches, the lamps, devices to avoid the effects of expansion and contraction through changes of temperature, meters to measure the current used, regulators to control the consumption of fuel. In a properly regulated system there ought to be no waste of fuel. The engine driver has an indicator which shows him exactly what current is going out, and he has simply to regulate his firing by this indicator. Moreover, by the use of a rheostat, he is also able to regulate the outgoing current so that he is able to maintain a perfect ratio

between the fuel consumed and the light evolved.

The question that determines the size and insulation of conductors is a commercial one, and is regulated by the relative economy of waste of energy or interest on capital expended. If an expenditure of £100 per mile saves you £10 a year in fuel, it is clearly better to expend £100 on your conductor. If, on the other hand, it would save you only £2 a year, it is better to utilize your capital elsewhere. Every inch of conductor means waste of energy; the shorter and heavier it is the less the waste; but as some waste is imperative, it is simply a matter of calculation to determine which shall be wasted least, capital or fuel.

The system is self-regulating, if the electromotive force is kept constant, and the resistance of the lamps be uniform. We have the dynamo machine at one end of the circuit, and a lamp at the other. The circuit is complete; a small current flows, which is determined by the resistance of the lamp alone, if the main conductors are made sufficiently large to neglect their resistance. Additions and subtractions of lamps only vary the resistance, and, therefore, the current. Turning off one lamp does not interfere with the rest. The limit of the number of lamps inserted is determined by their resistance and by the heating of the armature; hence the value of high resistance in the lamps, and low resistance in the armature of the dynamo machine. Every lamp induces, as it were, its own current. We have not a store of electricity which has to be subdivided, but we generate our energy as we want it. This is the promising feature of the system. It is a principle of multiplication, rather than of sub-division, and leads one to anticipate economy in its working. Mr. Edison's system has been worked out in detail, with a thoroughness and a mastery of the subject that can extract nothing but eulogy from his bitterest opponents. Many unkind things have been said of Mr. Edison and his promises; perhaps no one has been severer in this direction than myself. It is some gratification for me to be able to announce my belief that he has at last solved the problem that he set himself to solve, and to be able to describe to the Society the way in which he has solved it.

It may be taken as a rule, that any system dependent on the exercise of abnormal energy is certain sooner or later to break down; we all of us hate personal supervision, and personal supervision at home is a species of abnormal energy. This is the great secret of the success of gas. It is the cause of the slow progress of the arc light; but it is because the incandescent light promises to rival gas in this respect, that such a future is open to it.

The awards at the Paris Exhibition were liberally bestowed by the jury, perhaps too much so; but matters were hurried up towards the end, owing to political difficulties, and the conclusions were necessarily hasty. No proper measurements or tests were made by any jury, but a committee, presided over by M. Tresca, has since been formed to continue the work, and there is no doubt that most valuable results will be obtained, for the desire of the jury to procure reliable measurements has been very generally met by the exhibitors. I had great hopes of being able to give you the results to-night, but the reports are not yet complete.

We shall all, very soon, have a repetition on a different scale, and in a different way, at the Crystal Palace, and I have little doubt that, in its way, the Crystal Palace Exhibition will be as fine and as interesting as that of Paris.

DISCUSSION.

The Chairman said he could not open the discussion better than by calling on Mr. Johnson, the representative of Mr. Edison.

Mr. Johnson said he did not know that he could supplement what had been so well said by Mr. Preece, so as to add to the interest of the subject, but he should be ready to explain anything which had been left unexplained, and he would also illustrate, further, the use of some of the apparatus. He wished, however, to say that Mr. Edison's system was not merely a system of electric lighting; but the novelty of his system lay in this, that he contemplated the manufacture of electricity on a large scale at a central station, and its universal distribution

throughout the entire area of the city where it was established, to be used by uneducated or unscientific people, without the supervision of trained experts in the employment of the company. They proposed to put the electric light into houses in such a simplified form, and with such provisions, as to render supervision entirely unnecessary; to bring the lamps within the care of ordinary house servants, no matter how ignorant they might be; and in such a way that no damage or waste was possible. The electricity thus converted into light might also be converted into power, by means of an electro motor; and it might be utilized in a variety of ways, such as for ringing bells, &c. The annoyance of maintaining a battery, as well as its expense, had hitherto proved a bar to its general use, but when electricity could be supplied and paid for only as used, to be shown by a meter, an immense deal of work, such as driving sewing machines, &c., would be done by it. There had been a good deal of talk about a regulator, and Mr. Preece had shown that one might be made to maintain an even pressure throughout an entire district lighted from one station, no matter how many lamps were lighted by it. They preferred to have such a regulator with personal supervision, just as gas companies regulated the pressure on their mains as required, rather than employing any automatic device, which was liable to get out of order. [Mr. Johnson here showed how the amount of current could be increased or diminished at will, so that when fewer lights were in use, the quantity would be diminished accordingly.] The man in charge of the central station would regulate the current by a sample lamp kept alight there. He had been asked whether the replacement of the lamps, when used up, was expensive or difficult. In answer to that, he might say that in New York, where they were making arrangements to light up a central district of a mile square, they proposed to supply every consumer with all the lamps he might use, free from cost, simply charging the cost of the lamp in the current supplied and paid for on his meter. The first cost of the lamps was very small to them, and they therefore preferred supplying them to subjecting the consumer to the annoyance of having to purchase them. [Mr. Johnson here unscrewed a lamp, and attached another, to show the readiness with which a change could be effected.] A question had also been asked him, whether a single light could be raised or lowered; and there was a lamp made in which this was provided for, but it was more expensive and complicated, and was not recommended. There were very few cases where such would be required, because you need not leave a light on as in the case of gas, in order to light up when required, as you only had to turn it on, and it lit itself.

Sir Henry Tyler, K.C.B., moved a vote of thanks to Mr. Preece, but remarked that the paper hardly answered to the title, inasmuch as it was mainly devoted to an explanation of Mr. Edison's lamps, and he thought there might have been a little more time bestowed upon other lamps. He was far from wishing to disparage the Edison lamp, and no one had more sympathy than he had with American inventors; but he would suggest that the title of the paper should be altered when printed.

Mr. E. Crompton said he had been much interested in the paper, but he must concur to some extent in Sir H. Tyler's remarks. Many, if not all, of the merits of the Edison lamp were common to other incandescent lamps. He, therefore, thought Mr. Swan and Mr. Lane-Fox ought not to be passed over in silence, or Mr. Maxim, the other great American inventor. Mr. Preece had been rather hard on the arc systems, which he said had made comparatively little progress; but in reply to that, he would ask the meeting to look at the length and breadth of England, where, since that time last year, there had been from 900 to 1,000 installations of the electric light, which, with the exception of 30 or 40, were all on the arc system, and, with very few exceptions, they were all working most successfully. The incandescent systems were working equally successfully, but the whole system was an infant compared to the arc, and had not yet been worked on a sufficiently large scale to judge of its merits. It had hitherto been placed in circumstances not best suited for it. The lighting of the Savoy Theater was a great success, in his opinion, but no one could say that that vast open space could

not be lit more satisfactorily with arc lights, if good ones, and properly managed. The arc light hitherto had had to struggle with the great difficulty of getting homogeneous carbons; but new manufacturers were setting to work, and he believed the trade of making these carbons would soon become one of the great industries of the country. It required nothing but the enormous demand, now springing up, to produce splendid carbons, which would give a perfectly satisfactory light.

Mr. J. N. Shoolbred said he had nothing to add to Mr. Preece's descript on of the Paris Exhibition, but he thought his remarks as to the future sphere of the arc light and the incandescent light respectively should be somewhat modified. He did not think the arc light need be confined merely to large open spaces. It was a question of the enormous difference of mechanical energy; and a case which recently came under his notice would illustrate this. It was the interior of a building considerably larger than that hall, which it was found would require about 6-horse power to light it by the arc system, whilst on the incandescent system it would have taken nearly 40-horse power, and from 170 to 200 lights. With regard to the experiments shown that evening, he must fully concur in what had been said as to the beautifully steady character of the lights, but at the same time it was only fair that due credit should be given to other inventors.

Mr. Hugh Clements remarked that Mr. Edison had evidently gone beyond any one else, up to the present time, in the manufacture of his 20-ton machine at any rate. Mr. Preece, of course, could not enter fully into the details of all the lights; but he understood him now to withdraw a statement he had made on a former occasion, that it was impossible for private houses to be lit up by electricity from a central station. There was evident proof that this was being done in New York, and he hoped the time would soon come when they would see the same thing in London.

Captain Verney, R.N., said it might be interesting to the meeting to hear the opinion of one of the general public, entirely unconnected with any electrical interest. He had visited the Paris Exhibition twenty or thirty times, and had been many times in both the Edison and Swan rooms. He must say that he came away with the impression that on the whole the Lane-Fox was the most satisfactory exhibit. He was also much impressed with the beauty of the *Lampe Soleil*, which Mr. Preece had alluded to, but not described very minutely. One of its great beauties was, that you could introduce other substances as a bridge between the carbons, and thus vary the color and quality of the light. The light was exceedingly soft and agreeable, being generally overhead, and it seemed to him an enormous advantage to be able to introduce marble, magnesium, or some other substance, and so tone the light as to be suitable to the place to be illuminated. He hoped those who had the management of the Exhibition at Crystal Palace, would enable the general public to gather from it more information than was available at Paris. There they were furnished with an incomprehensible catalogue, referring to numbers which did not exist, and to rooms which could not be found. It was a most perplexing thing for any one with the average amount of intelligence and energy, to learn anything from the Paris Exhibition.

Mr. Lascelles Scott did not propose to launch upon the vexed question with which the discussion opened, further than to suggest that, as Mr. Preece had on former occasions spoken rather adversely to Mr. Edison, he felt constrained now, with more information, to do him full justice. He thought the time was hardly arrived to pronounce definitely that the arc light was only suitable for large open areas, and that the incandescent system was best for internal use, or *vice versa*, because in all probability, in a few years, such an opinion would be very much modified. Judging from his own small experience, he desired to place on record his opinion that probably the domestic lamp of the future would be one in which the prominent features of both systems were combined, which would illuminate a room alternately, or almost at the same time, by either a small arc or an incandescent lamp. There was already a system which professed to do something of the kind.

The Chairman said he thought that the last speaker had really given the answer to the objection raised by Sir H.

Tyler, by referring to Mr. Preece's desire to restore the equilibrium of the balance, which, on a former occasion, had been unduly depressed on one side. Passing from this matter and going to the real subject of the paper, they had before them a remarkable example of the incandescent light, and he thought they must all agree that if this light could be introduced into houses, in the same way as gas, and at no greater, or a very little greater, expense, it would be forthwith adopted. A lamp which did not vitiate the atmosphere in the least, which gave off but a small amount of heat, which was capable of being absolutely extinguished, and then renewed again in a moment, was one which all would willingly take instead of a gas lamp, which certainly did pollute the air, heated it inconveniently, and if there were too much pressure, or the burner were out of order, smoked and spoiled the furniture and pictures. Under these circumstances he thought it could not be doubted that if they could all, by a mere word, change their gas fittings and lights to such as they saw there, that word would be uttered; but then came the question, how near were they to that being practically and commercially possible? He believed they were very near to it. It had been said, and truly, of the electric light, as one of Dickens' characters said of the steam engine, that it was yet in its infancy. Sometimes infants grew up well, and became a pleasure to their parents; sometimes they grew up ill; but he believed this infant would turn out a credit to its parents, and that they would soon have the electric light laid on in the manner which had been stated. The difficulties at present attendant on applying it to individual houses, were those connected with the motive power, a large question which he could not then fully go into; but there was a system, somewhat inaccurately called "storage of electricity," by which there might be brought into any house a number of boxes, not storing electricity, but each containing an apparatus which had, by the agency of electricity, been put into a condition competent to develop electricity in an absolutely regular manner, a most needful quality for the satisfactory production of the incandescent light, although he must say no want of steadiness was observable from the working of the engine that evening. You could, therefore, by the aid of these boxes, practically have electricity brought into your house, as you had gazogenes, ready charged, or as he remembered many years ago, portable gas was carted to houses in this city. Unless there were some such system as that, persons who wanted to use the electric light had to resort to a motor of some kind, and there was the choice between steam engines and gas engines. A large steam engine at present was more economical than a gas engine, but on the other hand, it required a more skilled attendant. To work a gas engine, you had to do little more than turn a tap, and to oil occasionally; the stoker and engine driver were really at the gas works. The manager there supplied a regular flow and pressure of gas, and in that way the labor of attendance to each engine was reduced to a minimum. In the case of small engines, this non-necessity for skilled attendance reduced the cost practically far below that of a steam engine. For that reason, he believed, that the individual lighting of houses would be done by gas engines, and that if you took the gas with which your house was lighted, and applied it to work an engine, you would obtain a greater amount of light from incandescent lamps than by burning the gas direct. The calculation had been gone into very carefully, and were it not for the cost of replacing the lamps, it was quite clear that even now economy was considerably on the side of electricity. He was glad to hear from Mr. Johnson that in America the company preferred to include the replacement of the lamps in the fixed charge for the electricity; but that could hardly be done where each man had to produce his own electric current. A thousand hours was stated to be the average life of these lamps, some being much above and others much below the average. The other day a committee, of which he was a member, did not feel it safe to calculate the average at more than 500 hours, and then putting the cost of renewal at 5s., it turned out that that, added to the fuel, made the electric lighting rather dearer than gas, and they had deferred the consideration of the matter for a few weeks to obtain further information. But if

electricity could be laid on to houses, no doubt the problem would be, to a large extent, solved. One of the great difficulties was in the meter, but they had had one of a very ingenious and apparently efficient character exhibited that evening, and that might render practicable the establishment of a company for laying on electricity like gas or water, charging the consumer only for what he used. With regard to another point which had been considered a great difficulty—the division of the current—Mr. Preece said it was not really a divided current, but that each lamp induced its own current. That did not seem to him a very happy mode of expressing it, and he would endeavor to explain it in another way. Each of the lamps they would see, was situated between two parallel wires, from which went two small wires, which were attached to the filament of carbon in the lamp. Now, if instead of electricity they supposed water were being used, and that the wires represented the pipes, and one pipe contained a pressure of water, while the other acted as a return pipe, there being no connection between the two except by small pipes, represented by the wires going to each lamp, as long as only one of these small pipes was opened, the quantity which would pass would be only as much as could be transmitted by the one small connecting pipe; if two were opened, there would be double the quantity, and so on. Assuming for the moment that none of the pipes were open, then having once established a pressure of water, it required no energy to maintain it, if there were no leaks. You could bring the pressure up to a 100 lbs. on the square inch, and if there were no leak it would continue for ever; but if you established a connection between the pressure pipe and the return pipe, and allowed one gallon per minute to flow away, you must exert as much energy as would supply one gallon per minute under a pressure of 100 lbs. Similarly, if you established a connection between one wire and another, which allowed a given amount of electricity to pass, you must employ as much energy as would develop electricity equal in quantity and tension to that which had passed away: if you had ten wires connected, you must develop ten times as much energy. So that it was not in truth a sub-division of the current, but was allowing the current to flow, and regulating the amount of power to be put on accordingly. It would be easy to ascertain, by an indicator at the central station, what the demands were, and determine what should be the amount of pressure, as it were, in the conductors, and the number of horse power required to be developed in the engine, in order to supply the pressure. Mr. Johnson gave as an illustration the governor at a gas works, which controlled the pressure in the mains, and which had to be varied, from time to time, according to the draft upon them. At this time of the year, probably at half-past three, there would be a rise of pressure of so many tenths, another rise at four, again at half-past four, and so on until you got to the time when the theaters and shops were all using gas; and then came the maximum, which would be maintained until ten, when there would be a slight reduction, and a further reduction at midnight, when the uniform night pressure would come on and be maintained until about six; and then perhaps the day pressure would come on, and be maintained until the afternoon. A gas manager plotted this out on a sheet of paper which was affixed to the instrument, and this drew on the same sheet of paper, a trace showing the amounts and the durations of the pressure actually given, by the governors, so that, according to the way in which the pencil followed the lines already laid down, the manager could judge of how his directions had been carried out. Thus, by looking at the paper, you could tell if there had been a foggy day. If the day pressure provided for was say $\frac{1}{10}$, and the implement showed there had been $\frac{2}{10}$, you would know that there had been a fog, that the paper had had to be disregarded, and extra pressure put on. As he understood, provision would be made in the same way for increasing the electric current when required. With respect to the arc and incandescent lights, they would all agree that no one could dogmatize on what would be the light of the future, the whole matter being, as yet, too much in the trial stage; but, at present, he thought all would prefer the incandescent light for domestic illumination. It was admitted that the arc light was much more

economical, perhaps 10 to 1; Mr. Shoolbred said 8 to 1. Then Mr. Preece objected to the arc light being placed high up; but it was shown conclusively to the committee that sat on the lighting of Liverpool, that there really was no loss by placing the light high up. It was true the effect of the light diminished with the square of the distance, and that, therefore, a light a hundred feet up would give only one-hundredth part of the intensity of light that would be given by the same light if it were ten feet up; but, assuming an equal diverging angle for the really effective rays, it would, on the other hand, light a hundred times the area. The only difference, probably, would be the want of penetrating power in case of fogs.

The vote of thanks having been passed unanimously,

Mr. Preece, in reply, said it appeared that his sins had been rather of omission than commission, and this would be further explained by the opening paragraphs of his paper. It must also be remembered that that was the third or fourth time he had read a paper before the Society on electric lighting, and the sixth or seventh time he had spoken on the subject, and he had not, of course, again gone over ground he had already trodden. It would not be true to entitle his paper a description of the Edison light, as other matters were treated; but it was evident that what he had said about it, and what had been seen by the audience, had produced a very deep impression on their minds.

REPORTS ON THE SEWERS AND NOXIOUS SMELLS OF PARIS.

From "Le Genie Civil," for Abstracts of Institution of Civil Engineers.

The Commission appointed by the Prefecture of the Seine to inspect the sewers of Paris has issued two reports. The first treats of the sewers and the discharge of the waters, and the second deals with the methods of removing the bad smells by the various processes proposed.

The branchings off of the sewers have been found much fault with, as checking the flow and giving rise to bad smells, and they are defective in many places. The improvements proposed are a larger discharge of water, a continuous system of cleansing by keeping the bottom portion in constant motion by paddle boats or other means, and an enlargement of the culverts, especially at the junctions. The newest and largest sewers in Paris, along the Avenue de l'Opera, the Rue Richelieu, and the Rue Vivienne, are obstructed by water pipes, telegraph wires, &c., and consequently are difficult to cleanse. The section insisted on by the Commission as a minimum is a height of 6 feet 7 inches, and a breadth of 4 feet 3 inches. The injection of fecal and organic matters into the water-supplying sewers is strongly objected to; and it is urged that proper filters should be placed at the entrances to the sewers to retain all earth and sand which might tend to accumulate in the sewers and impede the flow.

The second report refers to the various chemical disinfectants which have been proposed, in addition to the main requirement of a much larger daily discharge of water through the sewers. All disinfectants act by means of their primary ingredients, consisting of either chlorine, sulphur, or nitrogen, producing by their decomposition in presence of moisture, hydrochloric, sulphuric, or nitric acid. Three special points were investigated, namely, disinfection, purification, and destruction of noxious germs.

In disinfecting, two substances have to be eliminated, namely, ammonia and its fatty aromatic compounds, and sulphuretted hydrogen. All acid compounds easily neutralize ammonia, which, moreover, is but little injurious, and the proposed disinfectants serve to remove it. Sulphuretted hydrogen is more difficult to deal with, especially in the cesspools, where it is present in large quantities; whilst in the sewers it decomposes rap-

idly in contact with the air, and seldom exists in them to any extent except when an unusual quantity of sewage has been discharged at one point. Mr. Madot's liquid, Mr. Charpentier's phenic sulphate of iron, Mr. Egasse's chloride of zinc, and Mr. Rafel's powder, serve to decompose it. The fatty and aromatic compounds of ammonia, which cause the worst smells, are more difficult to treat on account of their dangerous volatility. According to Mr. Huet, his disinfectant is able to prevent their generation by means of its antiseptic properties, but is powerless to stop their propagation when once generated. Mr. Grelle's English coal, in considerable quantities, is alone able to act upon them. Experiments are now being conducted on this subject.

Purification is a still more difficult problem, as not only have the waters to be disinfected, but the waters dirtied by the chemical products have also to be restored for consumption. From a series of experiments conducted by Messrs. Lévy and Allaire, it appears that the purification effected by each of the proposed disinfectants is very defective, the chloride of zinc and the Rafel powder alone producing admissible results; only a portion of the organic nitrogen in solution is precipitated, and the small germs are unaffected. The action of the disinfectants in purifying cesspools is more satisfactory; but the amount of organic nitrogen neutralized is not at all proportionate to the weight of disinfectant employed.

The germs must be destroyed by the use of antiseptics, such as alcohol, tar, tannin, salts of alumina, &c., or, the best of all antiseptics, cold. In a series of experiments on the action, in this respect, of the six disinfectants proposed, the phenic sulphate of iron proved the best for equal doses. Taking, however, the most effective result tried with a double dose, or $6\frac{3}{4}$ grains of Rafel powder to a gallon of water, which delayed the appearance of a germ for six days, it would cost £440,000 a year to apply this method to the 104,640,000 cubic yards of water annually discharged into the Seine from the Paris sewers. The operation of the disinfectants would accordingly, as regards germs, be expensive and incomplete, if not useless; and purification by means of the soil still presents the best solution of the problem. The report is summed up as follows:—the radical and complete solution to which one must strive to attain being still distant, the disinfectants, in spite of their insufficiency, still preserve their local value.

A NEW ELECTRICAL STORAGE BATTERY.

From "Nature."

The great utility of some thoroughly practical method of conserving electric force has caused a great deal of attention to be applied to the subject; no system of electric supply can be considered as perfect until some means is used to so store the force generated that it may be drawn off equally and regularly, and this whether the generator be on or off. If we take, as an example of electric supply, the present systems of electric lighting, it is at once seen, should an accident or stoppage take place in the machinery generating the current, the whole of the apparatus such as lamps or motor machines are influenced; should there be a reservoir of electricity between the generator and the apparatus of whatever sort for utilizing the force this inconvenience would not occur.

All the present systems of storing electricity depend on certain chemical changes produced by electrolysis.

I have gone through a long series of experiments on storing electricity and made many forms of cells, one being a porous pot containing dilute hydric sulphate and a sheet of lead, in an outer vessel containing a sheet of lead in solution of acetate of lead, the plate in the porous pot being made the positive electrode; this cell had the power of storing electricity, by peroxidizing the positive electrode, and depositing from the acetate of lead solution metallic lead on the negative electrode, the hydrogen having combined to form acetic acid. On discharging the peroxide is reduced, and the oxide formed during discharge on the other plate dissolves in the acetic acid,

forming the original solution of acetate of lead; by this means I eliminated the injurious effects of the hydrogen on charging.

During my experiments I found that red oxide of lead is a very bad conductor of electricity, and the peroxide a good conductor. I also discovered that by amalgamating lead plates with mercury a marked increase was immediately manifest in polarization effects, the plates becoming more uniformly and rapidly peroxidized when used as positive electrodes, and local action entirely disappearing. These mercury-amalgamated plates at once gave me an advance of other cells. I used them in many ways, constructing cells in which the positive plate was amalgamated, and the negative coated with red oxide, or with peroxide, produced by treating red oxide with dilute hydric nitrate till the brown precipitate of peroxide fell, the precipitate being washed and painted on the electrode. I also amalgamated the negative electrode simply. I found that in every way positive electrodes amalgamated produced the best results. I also made cells in which either peroxide or red oxide was formed into a porous conglomerate, using the conglomerates as electrodes, immersed in dilute hydric sulphate. I constructed cells with parallel plates, red oxide or peroxide being filled in between the plates; in this experiment red oxide is useless and peroxide efficient. In all these experiments I succeeded in storing electricity to different extents.

Having thoroughly satisfied myself that positive electrodes amalgamated with mercury were the best, I investigated the behavior of various forms of negative electrode, having in view the conservation of the hydrogen; this I thought to do by occluding the hydrogen in suitable electrodes, as spongy platinum or metallic palladium; but as both these methods would be useless, owing to expense, I did not even experiment on them.

I further thought of having negative electrodes, whose oxides should be soluble in the solution, and which could be redeposited from the solution, or of having metallic solutions from which metal could be deposited, the resulting solution being such that should, on the oxidation of the deposited metal, combine with the oxide and again form the original solution.

I thought that success in this manner would result in a powerful and constant source of stored energy, the cell would not polarize itself during discharge, as is the case in both Plante and Faure cells; in these cells the peroxide formed by the discharge produces a contrary electro-motive force.

Experimenting from this train of thought, the results I have obtained are such as to have an important practical bearing on the future of electric work.

The experiments comprised amalgamated lead as a positive electrode with negative electrodes composed of either zinc, iron or copper, in each case the solution between the electrodes being a salt of the metal composing the negative electrode. With zinc, sulphate of zinc was the solution; with iron, sulphate of iron; and with copper, sulphate of copper. In all these cases the results were not only far more powerful than with any form of cell I had previously devised, but also very constant, the polarization lasting many times longer than in any other form of cell. The cell with zinc negative electrode I discarded, owing to the necessity there would be to keep the zinc plate amalgamated to prevent local action; the iron negative electrode was set aside owing to the iron oxidizing when the cell was not in use. The cell having a negative electrode of copper, a positive electrode of lead amalgamated with mercury and a solution of cupric sulphate, I have adopted as a thoroughly economical, lasting and practical form of storage reservoir. The chemical changes in this cell are exceedingly interesting and beautiful, the cell being composed of a sheet of lead cleaned with dilute sulphuric acid and amalgamated thor oughly with mercury, and a sheet of thin copper a little shorter; the two sheets are perforated with a number of holes and then rolled in a spiral, separated by rubber bands cut every five inches, the holes in plates and cuts in rubber bands being to allow free circulation of the solution (the short plate being uppermost before rolling). This combination is immersed in a solution of cupric sulphate, and the amalgamated lead plate made the positive electrode of a suitable source

of electricity, the chemical action being that the oxygen of the decomposed solution combines with the lead, forming a perfectly even coating of the insoluble peroxide, the hydrogen replacing the copper of the solution, and the copper being deposited in the metallic state on the negative electrode. As the decomposition of the cupric sulphate proceeds the solution gradually loses its azure blue color, becoming more acid, and finally when the whole of the copper is deposited, we have the solution colorless and transformed into hydric sulphate and water, the positive electrode peroxidized and copper deposited on the negative electrode. During discharge the peroxide is reduced and the copper element oxidized, the oxide combining with the acid and forming cupric sulphate, the solution returning to its original color. This change of color forms a beautiful means of telling when the cell is charged; it is a veritable charging gauge. The power of this cell is very great and very constant; it can be made to last for hours, the time being dependent on the quantity of cupric sulphate decomposed.

I have, by the decomposition and recomposition of one pint of cupric sulphate, obtained over two hours' effective work in heating to a red heat one inch of No. 28 iron wire, the cell measuring internally 4 inches deep and 4 inches diameter.

I constructed cells with free crystals of cupric sulphate suspended in the solulution, and found that the presence of free crystals prevented the oxidation of the amalgamated lead electrode, it being essential that the solution become slightly acid before the peroxide will form. The cell during charging gives out a peculiar rattling noise, which I consider due to the deposition of copper on the negative electrode altering the form of the spiral.

A practical form of cell for storing purposes ought to be made, by fixing a series of amalgamated lead plates in a box in grooves, as in Cruikshank's trough battery, filling the interval between the plates with solution of cupric sulphate, and passing a current through of sufficient tension to overcome the contrary electromotive force of the series, the positive sides of the plates being peroxidized and copper deposited on the negative sides. I have two boxes on this plan, each containing twenty-five plates, the total being equivalent to fifty cells. By this means batteries of great tension can be charged from thirty Bunsens. A number of twenty-five plate boxes can be coupled for quantity of charging, and for tension during discharge. Twenty such boxes, one foot square, internal measurement, will give in series a battery of 500 pairs of one foot square plates.

It will be seen from the foregoing that this method of conserving energy has a wide field before it, and as it will benefit fellow-workers in science, placing in their hands a means of experimenting with powerful electric currents, I give it without reservation, freely and untrammeled by patent rights, for their use.

THE PENETRATION OF SEWER GAS INTO DWELLINGS.

By Dr. LISSAUER, of Dantzic.

From "Deutsche Vierteljahrschrift für öffentliche Gesundheitspflege," for Abstracts of Institution of Civil Engineers.

THE author states that, since the completion of the new drainage works of Dantzic, he has devoted much attention to the question of house connections and water traps. His general conclusion is that too little care is bestowed by the public upon these important matters, and that for various reasons the subject has been neglected. In all cases which have come under his notice the presence of sewer gas in dwelling houses has been due to obvious imperfections in the fittings, which were capable of being readily set right when once observed. Much ignorance concerning this subject prevails among all classes.

The author gives the results of ten experiments directed to ascertain the condition under which sewer gases may gain admission into dwellings, and the methods which may be adopted for their exclusion. He disclaims any attempt at

chemical or morphological examination as being incapable in the present state of knowledge of leading to true results.

The following experiments were carried out in the house, No. 25 Heiligergeiststrasse, Dantzic, which was fitted up in entire accordance with the prevailing ideas. The soil pipe was prolonged and carried up through the roof, and received from the first and second floors a sink and a closet on each floor, a closet on the ground floor, and a closet and a sink in the basement. The observations were conducted in the ground floor closet, and for convenience of access the closet apparatus was removed, together with the water supply, leaving exposed only the siphon trap (of the form in common use). The diameter of the siphon was 11 centimeters (4.33 inches); the depth of water beneath the dip of the trap—*i. e.*, the minimum height of water to close the trap—was 8 centimetres (3.15 inches); or a total contents of 1,100 cubic centimeters (1.936 pint). In order to fill the siphon to the overflow level an additional level of depth of 1.5 centimeter (0.59 inch) was required, bringing up the total volume of water in the bend of the siphon to 1,450 cubic centimeters (2,553 pints). The actual water seal was thus 1.5 centimetre (0.59 inch) in depth. In the first experiment the trap was completely emptied with a siphon, and observations of the air currents were taken by means of a lighted wax taper, placed at the bottom of the trap. The direction of the flame readily indicated the nature of the current, the general direction being towards the soil pipe, showing that the sewer was sucking air. When water was poured into the soil pipe on the upper floors the flame was violently agitated and sometimes blown out. Water was then poured into the trap so as just to fill it to the full height of the seal, and colored black in order that it might be better observed. Frequent measurements were taken of the liquid in the trap (three or four times daily) for five days, during which time the water seal was diminished by suction into the soil pipe and evaporation to a level of -0.2* (-0.078 inch), showing the seal to have become broken. But on the first day, ten hours after the beginning of the experiments, air had forced up the blackened water over the top of the trap, the seal having become reduced to 0.7 centimeter (0.27 inch). Among the general conclusions from this set of experiments the author states that a seal of 1.5 centimeter had, after a five or ten hours' use, become insufficient for its purpose. In the second experiment a more complex trap, shown in an illustration, was employed, with a seal of 40 centimeters (1.31 foot). This apparatus became, under certain conditions an annular siphon,* and completely emptied the trap in a few seconds. The result of this experiment went to prove that the sudden emptying of a bucket of water on the upper floors produced such a compression in the lower part of the soil pipe as to correspond with a manometrical rise of from 1 centimeter to 2 centmeters (0.39 inch to 0.78 inch). The third set of experiments were carried out with another apparatus, shown in an illustration, and directed specially to ascertain and measure the small fluctuations in the pressure of the gases in the soil pipe. Arrangements were made to keep the water in the trap at a uniform level (*i.e.*, to restore all water drawn through the trap) by means of a double siphon connected with a store vessel containing a measured quantity of water. This store bottle the author names the "Restitutor." The result of this set of experiments proved that the water in the trap could easily be automatically maintained at one uniform level by a simple siphon apparatus. Further, that the suction down the soil pipe is such that on all ordinary occasions it represents a rise of from 0.1 centimeter to 0.2 centimeter (1.039 inch to 0.078 inch) in a manometer. On very stormy days this difference may at times rise to 0.6 centimeter (0.234 inch). The outward pressure from the soil pipe into the house caused by the use of the upper closets may correspond with a column of water from 1.6 centimeter to 2.2 centimeters (0.63 inch to 0.87 inch) in height.

In the fourth set of experiments a siphon trap was employed which had its front formed of glass, so that the height of the water on each side of the dip could be accurately observed, and measured by millimetric scales fixed in either

* That is, below the level of the dip of the siphon.

* By the same action as has been observed in Field's annular siphon and flush tank.

limb of the inverted siphon. The water employed was a soda solution, and strips of turmeric paper were suspended to show the height to which the water was blown up in the passage of gases through the seal. The depth of the seal was at first 2.5 centimeters (0.98 inch). Numerous tests were made of the seal by throwing down buckets of water in the upper closets, &c. This set of experiments proved that the utmost pressure of the gases did not exceed that of a column of water 2 centimeters (0.78 inch) in height. A seal of 2.5 centimeters (0.98 inch) was capable of resisting all pressure of gases in the soil pipe for five days, while the closets throughout the house were in ordinary use, and only gave way on the sixth day, when the seal had been reduced to 1.3 centimeter (0.51 inch). Nine buckets of water rapidly thrown down in the upper closets sufficed to break a seal of 2.5 centimeters.

The fifth experiment was conducted at 37, Jopengasse, with a similar apparatus to the last, but with a seal of 3 centimeters (1.18 inch). In this case an opening of 3 centimeters was made in the siphon so as to afford direct ventilation into the open air, and thus provide an escape for the confined gases other than by forcing the seal. By this means the pressure was so reduced that the utmost movement of the water in the trap was reduced to from 1 millimeter to 2 millimeters (0.039 inch to 0.078 inch). The sixth set of experiments was conducted with a sink trap, containing only 250 cubic centimeters (0.44 pint), and which required fifty-two days to become wholly exhausted; though in one week the level had fallen from 4.4 centimeters (1.74 inch to 3.1 centimeters (1.21 inch), and in eighteen days to 2.6 centimeters (1.02 inch). In the seventh set of observations a perforation was made in this trap to ventilate it, and sundry experiments with large volumes of water thrown down the closet were carried out. In the eighth set of experiments the water used in the trap was spring water, to see whether the absorption of sewer gas had anything to do with the rapidity with which the seal was forced. The result proved that *cæteris paribus* a trap was able to resist the passage of sewer gas the longer the water it contained required for its saturation with the gases. The next experiment was directed to prove the reverse of this axiom, and water saturated with carbonic acid gas was employed. In this case, after five buckets of water had been thrown down the soil pipe, the trap was forced; while it had required nineteen buckets of water to force a trap containing an equal volume of clear spring water. The tenth and last set of experiments were made on the same small sink trap, but provided with a "Restitutor," as in No. 3; and it was found that this apparatus enabled the water in this trap to be kept automatically at any required level.

The author next gives ten instances of faulty house connections and cases of illness connected therewith, and finishes with the recommendation that all domestic sanitary arrangements and apparatus should be placed under the control and subject to the inspection of the local authority. He advises the employment of a separate ventilating pipe alongside the soil pipe, carried up above the roof and placed in free communication with the open air, into which pipe all the traps are to be ventilated by openings, not less than 3 centimeters (1.18 inch) in diameter, situated between the water seal and the soil pipe. He speaks of the English system of disconnection at the foot of the soil pipe as unknown to him by practical experience, and as of little use in Dantzic, where the street sewers are so formed as to suck air (which is in itself a protection to the houses), and where pressure of gases, tending to force their way into dwellings, only occurs at intervals in the form of gusts (*stossweise*). He concludes by stating that in all new dwellings the authorities of Dantzic have made compulsory the plan he advocates of direct ventilation of the siphon trap.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—The meeting of December 3, 1881, was the first held in the new rooms. The matters of scientific interest presented, were as follows: Mr. John E. Codman exhibited drawings of and described Nicholson's Fire Escape, which consists of a fireproof brick tower, octagonal externally and cylindrical internally, with central shaft about 18 inches diameter, around which is formed a winding passage of a U-shaped section, 2 ft. 3 in. in width, with smooth or glazed surface, and inclined at an angle 35°, with retarding curves of less gradi-

ent. Fireproof doors would connect with each floor and roof, and a vestibule with the surface ground below. It is intended that those escaping shall assume a sitting posture on entering the spiral and slide to the bottom, and it is claimed to be safer than other escapes for those unaccustomed to ladders, or weakened by fright or excitement. Mr. Codman also exhibited a working model of Deschamp's Angular Shaft Coupler, by means of which shafting can be offsetted when bearings are displaced or bent to any angle, from 0° to 90°. Prof. L. M. Haupt exhibited an Interpolating Scale, devised by Prof. W. S. Chaplin, of University of Tokio, Japan, by means of which any intermediate point of elevation between two known points, on a topographical plane, can be readily determined. He also read a short discussion of Mr. S. C. Gant's scheme of Underground Railroads in Philadelphia, presented at last meeting. Prof. Haupt, while decidedly favoring rapid transit and admitting the practicability of the construction proposed, considers Mr. Gant's estimate entirely too low, and, by comparison with the Union Tunnel at Baltimore, he estimates that that portion of the tunnel system which Mr. Gant estimates at $1,733,710 would cost $6,051,500, or about three and one-half times the original estimate, and even this he considers too low for the plan proposed. Prof. Haupt also read a paper upon Railroad Crossties, touching especially upon the desirability of an iron tie, a model of which he exhibited at the last meeting. Mr. T. Earl Collins exhibited and described a model of the Camerer Valve Motion. Mr. Wilfred Lewis exhibited a moveable head T square, the head of which is held very firmly in position by means of a cone clutch.

DECEMBER 17th, 1881.

Mr. T. M. Cleemann exhibited photographs of and described several examples of ancient Roman masonry. He regarded as the most important and remarkable for its excellent preservation, the aqueduct at Nismes, in the south of France, which was built at about the beginning of the Christain era, and represents the engineering skill of the Romans when their power was at its height. It consists of three tiers of arches, the two lower being similar and superposed on one another, the upper tier of much smaller dimensions, upon the top of which runs the water channel. The various arches differ in span—lacking the regularity and conformity to one pattern of modern works. The center line was likewise not perfectly true, showing that no transit had been used by the engineer in charge.

The approximate dimensions are as follows: largest arch, span 75 ft., piers 15 ft. (by Rankine's rule about 11½ ft.); ring stones 4 ft. thick (Rankine, 2½ ft.); water channel, originally 6 ft. × 4 ft., rectangular, now reduced by calcareous deposit nearly 1 ft. thick. Bond of piers, alternate header and stretcher, in courses of about 18 inches.

In the lower tier the arch stones are laid in four, and in the middle tier in three rings, without bond; in the upper tier in two rings, breaking joint. Closely-laid rings, without bond, was also observed in a Roman bridge at Avignon.

Numerous stones projecting from intrados and face are supposed to have been left to support centers and scaffolding during construction. The whole structure seems to be founded on rock.

An aqueduct near Rome and the Basilica of Constantine were also described. The latter was built about A. D. 300, and consists of bold arches, 66 ft. span, of brick, one abutment of which is only about one-third of the radius of the arch, which is considerably thinner than Rankine's rule would require, but the use of old Roman cement has reduced the structure to almost a monolith.

Mr. Thomas C. McCollum contributed a block, cut from a pile which had been under water but three months near Pensacola, Fla., and, not having been creosoted, was completely honeycombed.

Prof. L. M. Haupt read a letter from Mr. Walter Shanly, C.E., upon the water transportation routes from the North-west to Europe.

ENGINEERING NOTES.

THE PANAMA CANAL.—A complete account has now been published of the proceedings of the superior consulting committee of the Panama Canal works, which assembled in Paris for its first session on November 25. A report drawn up by the consulting engineer, containing the proposals of the administrative council for the second phase of the work, was laid before the Commission, and served as the basis of its deliberations. It is considered that the best opening for the canal at its eastern end into the Bay of Simon, will be by way of the mouth of Folks' River. A cutting through the Mindi Hills would bring the canal from Folks' River to join the River Chagres, whose bed is also to be taken advantage of for a considerable distance; and it is proposed to begin it very soon, and make a sort of temporary canal for immediate use on the line of the great one, so as to establish water communication with Gatun, on the Chagres. The Administration asked permission to begin work at once at two points; upon the rocks between the falls of the Obispo, and at the highest point of the cuttings, the top of the Cerro Culebra, where, however, the soil is argillaceous. Here preliminary cuttings will be made, which will give more accurate knowledge of the nature of the ground than can be derived from any number of soundings. According as the earth is removed, it will first be piled up in banks to protect the cuttings from becoming drains for rain water, and then gradually be used for a tramway from the Culebra working to the Gamboa dam, to convey thither all the remaining débris. We have mentioned this dam before, and now need only add that owing to the great depth at which the solid rock lies at that spot, it has been decided not to attempt to make any foundation, but simply to heap the materials on the surface of the ground. A wall of great blocks of stone will cross the valley, inside and above it will be laid in order smaller blocks, rough stones,

pebbles, gravel, sand, and clay, and the Culebra débris. Arrangements will be made to prevent flooding during the course of the work. The Commission assented (after deliberation) to these and all other proposals of the Administration, with a few slight qualifications.

THE ST. GOTHARD TUNNEL.—We have several times spoken of the difficulties with which M. Favre had to contend when he became contractor against much opposition for the construction of this tunnel, and of the obstructiveness by which even some members of the St. Gothard Railway Company prevented his commencement and proper progress of the work. Since the tunnel has been drawing towards completion the company has several times commenced and threatened to commence proceedings against the executors of M. Favre on account of its non-completion to date It is, however, completed long before the company's lines are ready to work it. The tunnel company has thus gained an unenviable notoriety; yet, according to the *Times* Geneva correspondent, the company is again commencing fresh proceedings against the executors of the late Louis Favre, the contractor, for the recovery of the penalties which it alleges he has incurred by exceeding the time originally fixed for the completion of the undertaking. "The company has even gone the length of confiscating some of the securities lodged with them as caution. Considering that, inasmuch as the lines of access are not yet finished, the company is in no way injured by the delay; that the delay is due rather to its *lâches* than any fault of Favre or his representatives; and that Favre lost the whole of his fortune by the contract, this proceeding is regarded as harsh and unfair in the extreme. The press is unanimous in denouncing the conduct of the company, and there is a general demand for the intervention of the Federal Council, who are empowered to settle all disputes arising out of the construction of the tunnel, to prevent the consummation of an injustice which would dishonor the whole country." According to official figures the cost of this tunnel from first to last has been 56,808,620f., or £2,272,344..

RAILWAY NOTES.

THE WESTINGHOUSE CONTINUOUS BRAKE.—It is about ten years since Mr. George Westinghouse first came over to this country with the object of inducing railway companies in this country and on the Continent to adopt his system of continuous air brake, which had at that time found a large and very useful application on the railways of the United States. At that time continuous brakes were only exceptionally used on English railways, and not at all on the Continent. Here the necessity for them was realized, but not so fully as a few years later, when the increase in the number of trains and the acceleration of speeds rendered some efficient means of controlling trains absolutely necessary. The Board of Trade took action in the matter by a series of exhaustive trials, and having satisfied themselves as to the requirements of an efficient brake, and also as what could be done within practical working limits, laid down a series of conditions sufficiently stringent, but capable of being fulfilled by one system—the Westinghouse automatic. This was a very considerable advance over the original Westinghouse continuous air brake, which was, however, until the introduction of the improved system, the most efficient that had been introduced. These trials took place in June, 1875, and were only one series of a large number carried out before and since both in this country and on the Continent, and which proved conclusively the superiority of the Westinghouse brake over all the other systems with which it came into competition. In spite of this undoubted superiority, the adoption of the automatic air brake proceeded but very slowly on English railways, owing to causes with which we need not trouble ourselves now. But however slow this progress, it has been at all events steady, and during the last two years has advanced with more rapid steps, while on the Continent the adoption of the Westinghouse automatic brake may be said, as regards France and Belgium, to be universal. An examination of the results obtained will show that Mr. Westinghouse has established his system in Europe on as strong a basis as in the United States. Up to the 25th of last month the number of automatic brakes in use or ordered for immediate application were as given in the following table :

Country.	Engines.	Carriages.
England	1,087	7,719
France	1,416	7,193
Belgium	359	1,728
Germany	63	105
Austria	4	32
Russia	64	51
Holland	59	208
Italy	11	35
Sweden	1	6
India	6	60
New South Wales	66	124
South Australia	27	18
Queensland	1	11
United States	3,435	12,270
	6,599	29,560

In England the system is in use on fourteen different railways, the chief of which are the Northeastern, with 328 engines and 2343 carriages, the London, Brighton and South Coast Railway, with 256 engines and 2116 carriages, and the Great Eastern with 136 engines and 1,064 carriages The North British, the Caledonian and the Glasgow and Southwestern also have their stock fitted with the brake. In France the system may be said to be universally adopted, since it is the standard brake on the Western, Ceinture, the Paris Lyons and Mediterranean ; the Orleans and Midi have accepted it. The State railways of France have not yet definitely decided, and the Northern, which for some time has employed the vacuum brake, has still that system in use. There is little doubt, however, that with a uniform system throughout the other railways, the Northern

will soon decide on making a change. In Belgium, on the whole *reseau* of State railways, the Westinghouse automatic brake is used, it having been very early adopted by the Government, which has every reason to be satisfied with the wisdom of their selection. In the United States it is of course recognized as the standard system, no less than 190 railway companies employing it As regards the non-automatic or early continuous brake, its use continues to a large extent in America, there being in service on United States lines, 2,579 gines and 11,389 cars fitted, while in England and the colonies there are 58 engines and 399 carriages running with the brakes. Thus the total of railway stock to which Westinghouse brakes have been applied and are to-day in use amount to no less than 9,236 engines and 41,349 carriages. These figures are more conclusive than any argument could be, of the acknowledged efficiency of the system. Despite the hesitation, indifference, and in some cases obstructiveness of locomotive superintendents in this country, the example set by Belgium and France (in both of which countries the automatic brake was promptly decided upon), will doubtless be followed here as soon as public and official pressure enforces general action. The Westinghouse Brake Company, Limited, employs more than 500 men manufacturing automatic brake apparatus in their various establishments in Europe, the present capacity for turning out work being equal to 1,200 carriages and a proportionate number of locomotives per month.

M. PAPON, a deputy for the department of the Eure, has introduced into the Chamber of Deputies a bill for the immediate purchase of the whole of the French railways by the Government. The scheme provides for the division of the great lines into sections of 2500 kilometers, each of which is to be managed by a company under the general supervision of the Minstry of Public Works. M. Papon's proposal is already meeting with considerable opposition, as it ought.

THE Marseilles correspondent of the *Daily News* writes that several Frenchmen, living at Sfax, in Tunis, have formed themselves into a committee, under the presidency of Dr. Fernand Laffitte, with the intention of carrying out the suggested railway across the Sahara. A superior commission has been appointed to examine the means of uniting the Senegal with the Niger, and Algiers with Timbucktoo, by railway, and of uniting by a combination of railways the two large African colonies. However, the Trans-Sahara Railway will give access only to a very limited part of the Soudan.

THE Midland Railway has refused, it is said, to carry the new big bell for St. Paul's from Loughborough to London, on account of its weight exceeding the carrying powers of any of their trucks. *Colonies and India* thinks that the directors of this and other English railways might take a hint from the "cars" employed on the Canadian railways, where a "new combination box-car" has lately been introduced which will carry 30 tons of freight. It lately took a load of 9,800 bushels of wheat, weighing 48,000 lbs., the whole of which was unloaded in one minute; after which it carried 16,080 ft. of green lumber, weighing 70,000 lbs., in one journey; and followed this up by taking the enormous load of 1000 bushels of barley.

AN American company is making proposals to the Transvaal Government to construct the Delagoa Bay Railway. It is reported, says the *Colonies and India*, that England has offered to give the telegraph line to the local Government.

FROM the report on a recent accident on the English Great Western Railway it appears that it is considered safe to work the block system with a much less margin of safety than is considered necessary upon many other lines. Under their regulations "line clear" without any reservation or caution can be given when there is an obstruction on the line a certain distance, specified in each separate case, inside the home signal, which distance in the case of Ely was 107 yards. Upon some lines, in such a case, the line would have been blocked, and on others the train would have been allowed to move forward only with a caution. As at present worked, the block regulations upon this line do not sufficiently provide for the safety of the public.

THIS winter two new State lines are to be commended in India, both as protective works against famine. The first is the meter guage line, from Rewari on the Rajpootana Railway—and extending to Hissar. It will be carried on ultimately to Ferozepore, and when finished will greatly shorten the communications between the Punjab and Bombay. The second line, also of the meter guage, will connect Bellary with Goa and the Murmagao Railway, and will have a branch from Gadac to Sholapore, on the Great Indian Peninsula line.

SURVEYS are shortly to be commenced of the three alternative routes between Calcutta and Nandgaon, the present terminus of the Nagpore-Chatisgarh Railway, and and the long-talked-of direct Calcutta and Bombay Railway may shortly become an accomplished fact. Another survey party will examine the country between Mymensing and Gowhatty, in Assam. The country north of the Ganges, from a point opposite Patna to Baraitch, through Goruckpore, is also to be explored, and it is rumored that if the Government decides on a railway there, its construction will be entrusted to private enterprise. There is also talk, says *The Colonies and India*, of surveying for a line to connect Bundelcund with the Central Provinces system.

RAILWAY traffic in Germany and Austria has this year been increasing so generally as to leave no doubt as to the revival of business in those countries, the statistics include the nine months ending September last. On the main lines, State as well as private, of Germany, the increase was at the rate of 3¼ per

cent. On the lines running through Austria and Hungary the increase was 6 per cent.; but the mileage of these lines had also extended 6.9 per cent. The purely Austrian railways showed an increase of 4 per cent., while the length of mileage was extended 2.9 per cent. The earnings of the purely Hungarian lines showed an increase of 5 per cent., while the mileage increased 3.9 per cent.

Of the 969 tires which failed on British railways during the nine months ending 30th September, 50 were engine tires, 32 were tender tires, 6 were carriage tires, 44 were van tires, and 837 were wagon tires; of the wagons, 684 belonged to owners other than the railway companies; 739 tires were made of iron and 230 of steel; 33 of the tires were fastened to their wheels by Gibson's patent method, 19 by Beattie's patent, 12 by Mansell's patent, 34 by Drummond's patent, all of which remained on their wheels when they failed; 852 tires were fastened to their wheels by bolts or rivets, of which 5 left their wheels when they failed; 19 tires were secured to their wheels by various other methods, none of which left their wheels; 153 tires broke at rivet holes, 224 in the solid, 6 at the weld, and 616 split longitudinally or bulged.

At the commencement of last year there were, according to official reports, 5112 miles of railway in operation in Italy, with 1492 locomotives, 4544 passenger cars, and 24,093 freight cars for equipment. Their average earnings per mile, in 1879, were £1,232 per mile, the working expenses £756, leaving as net earnings, £476, which is at the rate of 2.5 per cent., nearly, on the capital invested. The earnings from passengers were very nearly as great as the ordinary freight earnings, but a very large amount—nearly an eighth of the total earnings—was from the express and other freight carried on passenger trains; and there were on this system of less than 6000 miles, in the course of the year, 256 collisions and 400 derailments of trains, by which twenty-nine persons were killed and 439 injured.

ORDNANCE AND NAVAL.

Torpedo Boat Trial.—A trial trip took place a few days ago near Dantzig, with a new torpedo boat, built for the German Admiralty, and engined by Mr. T. Schichau, of Elbing, Prussia. The contract under which these engines were built, specified that with a total weight of 9000 lbs. for engine and boiler, inclusive of water, the engine should indicate 100 horse power. This performance was, however, by far exceeded at the trial, the engine indicating during a trial trip of five hours, 170 horse power, while the total weight amounted o only 9880 lbs., or 58.2 lbs. per indicated horse power. The performance was in every way highly satisfactory. The engines of the compound type have cylinders of 9½ in. and 17½ in., with 17½ in. stroke, and work at a speed of from 400 to 440 revolutions per minute, diagrams being taken during the trial with one of Schaffer and Budenburg's high speed indicators. We hope on a future occasion to have more to say about these engines, which possess several striking features, and we also hope to be able to show some indicator diagrams obtained from them.

We are informed that Sir William Palliser is of opinion, from his many tests to destruction of his converted guns, that the injury to a Spanish gun by a violent pressure set up in the bore, bulging the tube so much as to crack the casing above and below longitudinally, and thus, as usual when this happens, according to his experience, separating the body of the gun from the breech, the latter being blown to the rear. Sir William has written to the Spanish Minister in London to ask that full information may be afforded to him on the subject.

Further information has reached this country concerning Ericsson's torpedo boat, the Destroyer. It appears that he has abandoned the use of steam for ejecting his torpedo from the boat, and uses gunpowder instead. Thus the boat really carries a submarine breech-loading gun. The target referred to in *The Engineer*, for November 18th, was made of Manila rope and wooden slats. A dummy projectile, or one of wood only, was discharged from the gun. The muzzle of the gun was 6½ ft. below the surface of the water. The charge was 12 lbs. of giant powder. The projectile was 25½ ft. long. The gun is aimed and discharged by electricity, operated by the steersman. The projectile traversed the target at a depth of 5 ft. beneath the surface of the water, appeared on the surface about 100 ft. beyond, and continued its course with considerable velocity for 200 ft. more. A submarine distance of 400 ft. was made in three seconds, although the gun charge was, as we have said, but 12 lbs.

IRON AND STEEL NOTES.

Steel for Magnets.—At the Society of Telegraph Engineers on Thursday week, Mr Stroh drew attention to the fact that it was difficult to get good steel in this country for the manufacture of magnets. Two pieces cut from the same bar gave different results. In France, on the other hand, he found that very powerful magnets of reliable quality were made from the cast steel of MM. Charrière and Co. The superior power of the Gower-Bell telephone was largely due to the use of French steel. If good steel were used Mr. Stroh had found that the mode of magnetizing did not matter. Mr. Le Neve Foster, in reply to Mr. Stroh, said that he had used French steel at Silvertown for over a year, and that its excellent magnetic property was due to its containing some three per cent. of tungsten.—*Engineering.*

BOOK NOTICES.

ADOLPH STRECKER'S SHORT TEXT-BOOK OF ORGANIC CHEMISTRY. By Dr. Johannes Wislicennes. Translated and edited by N. H. Hodgkinson, Ph. D. and A. J. Greenaway. London.

It is only in view of the fact that the subject is limitless, and even the list of its topics endless, that this treatise is termed a short Text-Book. Over seven hundred and fifty royal octavo pages of closely printed matter, with a few cuts, are employed in exhibiting the shortness of this essay.

No chemist, however, we presume, will be deterred from securing the book, if he has any need of the knowledge of recent discoveries in this department of research, nor will he hesitate to accept the book as an authority.

The molecular constitution of organic compounds, together with their physical properties and the theory of the formation of their derivatives, are more fully presented than the details of the processes of manufacture.

A TREATISE ON CHEMISTRY—Vol. 3, Part 1—ORGANIC CHEMISTRY. By H. E. Roscoe, F.R.S., and C. Schoolemmer, F R.S. New York: Appleton & Company.

The first two volumes of this fine work are already well known to chemical students. The present volume will, doubtless, prove equal to the expectations raised by the former. As the title page indicates, the work is not yet complete, and the real extent of volume three can hardly be foretold at present.

Certain of the subjects may, however, be assumed to be finished in Part I, and these are of great interest and value to all students of chemistry. We refer chiefly to the description of the processes of organic analysis as devised by the prominent analysts. The determination of vapor densities and of the molecular formulæ are also of especial value.

Aside from the above subjects, which are beautifully illustrated, the remainder of this volume is mostly devoted to the hydro-carbons and their deriva ives.

The volume contains 724 pages.

THE SYSTEM OF CALCULATING DIAMETER, CIRCUMFERENCE, AREA, AND SQUARING THE CIRCLE, TOGETHER WITH INTEREST AND MISCELLANEOUS TABLES. By James Morton. Philadelphia: Published by the Author.

This book is not quite as bad as its title would seem to indicate. Although the useful parts can hardly prove serviceable to the novice who may need them, by reason of the rubbish which obscures them, or the curious scraps of misinformation with which the substantial parts of the book are interpolated.

It does not, however, require much discrimination to detect the original portions of the book. These should be carefully omitted by the learner. As for the remaining portions consisting of tabular matter, they are obtainable in cheap form in school books and pocket table-books everywhere.

Only an inordinate fondness for mere arithmetical computation, especially for fifteen-place decimals could have prompted the writing of this book.

THE ACTUAL PRESSURE OF EARTHWORK. By Benjamin Baker, M. I. C. E. Van Nostrand's Science Series, No. 56. New York: D. Van Nostrand. Price, 50 Cents.

This little book contains one of the most valuable of the practical essays of the Institution of Civil Engineers. Written by an engineer of large experience and with a thorough knowledge of the literature of the subject, the paper is of great value to all who are likely to be confronted with the problem of a high retaining wall.

Engineers who dissent from Mr. Baker's view in regard to the theory of earth pressure, will still find much of value in the book, in the examples cited, of walls that have stood or failed in apparent contradiction of the accepted rules.

In connection with this view of the work, Prof. Cain's article in this present issue of the magazine may be read with profit.

The price of the work we don't know; whatever it is, it is too much.

MISCELLANEOUS.

THE JABLOCHKOFF ELECTRIC LIGHT.—A portion of the Bon Marché at Brixton was illuminated with the Jablochkoff electric light, and the installation will probably be followed by an extension over the whole building. This system of lighting has had a long and successful career in a number of industrial establishments in this country, among which we may mention Messrs. Shoolbred & Co., who commenced its use three years ago with forty lights, now to be increased to sixty; Messrs. Nicols & Son since 1879, and Mr. W. Whiteley during the last twelve months. All of these gentlemen speak enthusiastically (after their prolonged experience) of the superiority of the arc light over gas, and it is an important fact that after three years' work, the generators and lamp at Messrs. Shoolbred are in as good a condition as when they were first started. The Société Générale d'Électricité have now lighted the Thames Embankment since the 16th of December, 1878, and during that time there has been no suspension of the light through any failure of the system, the only periods when it was not used being during alteration involved from extension of the company's contracts with the Board of Works.—*Engineering.*

REFRIGERATED MEAT FROM MELBOURNE.—Some interesting information has just been received in Glasgow from Melbourne regarding the new industry in shipping refrigerated fresh meat to the mother country, an industry which may be said to have been originated by Messrs. John Bell & Sons, of Glasgow, a firm of merchant butchers. The correspondent, writing on the 25th of October, says that the steamer "Europa" had nearly finished taking on board 8,000 sheep and 500 lambs. No beef was to be sent, as large cattle was too high in price. The "Europa" had

also a quantity of butter and a large shipment of wool on board. She had been fitted with a freezing machine constructed, the correspondent says, on an entirely new principle. It was made on the banks of the Yarra at Melbourne, and is worked by two steam engines of 20 horse power combined, and has three compressing cylinders and three expanding cylinders. The engineer having the shipment in charge (Mr. Hilliard) had expressed the utmost confidence in taking the meat to London in prime condition. The meat had been prepared at Maribyrnong, near Melbourne, and was shipped by the Australian Frozen Meat Preserving Company, at whose works there is in use a machine similar to the one fitted on board the "Europa."—*Engineering.*

THE USE OF PARAFFIN COMPOUNDS FOR ELECTRICAL INSULATION.—In the course of our notices on the Exhibition of Electricity at Paris, we ventured to point out that the magnificent collection of electrical apparatus in the Palais l'Industrie, besides introducing to the general public a certain number of new applications of electrical science, would also display as novelties many reinventions of old discoveries, and many visitors to the Exhibition must have recognized in walking through the galleries several old friends in new dresses, and still oftener with new names. This was especially the case in connection with electric lamps, many of which bearing widely different names, possessing such strongly marked family likeness, that their descent from a common ancestor was obvious. And the same remark is applicable in a somewhat less degree to several of the dynamo electric machines which were exhibited at Paris. In another department of electric science, also, history (as evidenced by the Paris Exhibition) has a strong tendency to repeat itself. In a recent article we described the very interesting exhibits of Messrs. W. T. Henley & Co., and of MM. Berthould, Borel, and Cie., in the former of which an insulating material is introduced composed of a mixture of solid paraffin and india rubber, and in the latter an insulating substance is employed, which is compounded of paraffin and resin, while in another part Messrs. Latimer Clark, Muirhead & Co. exhibited a new compound insulating material to which the name "nigrite" has been given, and which is a mixture of india-rubber and ozokerit. In connection with these inventions it is an interesting historical fact that as far back as the year 1865, Professor Abel, C.B., the eminent director of the laboratories of the Royal Arsenal at Woolwich, not only conceived the idea, but took out a patent for insulating materials for electrical purposes, consisting of compounds of india rubber with paraffin or beeswax, stearine, spermaceti, or other solid fatty substances, or mixtures thereof, as well as of gutta-percha, treated in the same way, and in his published specification, Professor Abel describes methods of preparing the mixtures, as well as of covering electrical conductors with it, and there can be no doubt that the publication of this invention seventeen years ago has in the light of recent improvements become of considerable historical interest. Another point of interest is the fact that almost all the submarine electric cables that have been constructed are but little more than perfected modifications of the first submarine cable that was ever laid, namely, that designed by Mr. T. R. Crampton, C.E., and laid by him between Dover and Calais in the year 1851, and in the Exhibition specimens of this cable were to be seen, exhibited side by side with the splendid collection of specimens of cables made by the Telegraph Construction and Maintenance Company, and which have already laid the foundation for a network which bids fair to cover the whole civilized world.—*Engineering.*

M. MAICHE has found by experiment that sounds from two separate sources can be sent and received simultaneously on one wire. He uses at the receiving station two telephones of different resistances, and at the transmitting station caused a musical box to be set going on a microphone of small resistance, whilst an induction telephone transmitter was spoken into at the same time. The musical sounds were reproduced in the telephone which had the least resistance, and the vocal sounds in the other, so that with the two telephones to the ears the music could be heard by one ear and the speech by the other.

AT a recent meeting of the Academie des Sciéncés a paper was read by M. Lévy on the numerical application of the theory of maximum yield of two dynamo-electric machines employed for the transmission of power. Referring to a case discussed by M. Deprez, he shows that, by adopting different resistances, he would obtain 10-horse power at 50 kilometers, with a maximum electromotive force of 5,356 volts, instead of about 7,000.

THE dry distillation of wood and the utilization and refining of the products appear to be making great headway in Germany. The manufacture of aniline requires large quantities of wood alcohol, which is now purified much more cheaply and better than hitherto. Acetic acid is now made of a quality not alone sufficient for technical purposes but for table use. The charcoal is compressed into cylindrical blocks weighing about one-tenth of a pound. They are largely used, a contemporary says, for domestic purposes, as they burn without smoke.

AN autodynamic watch or clock has, it is said, been made by Mr. Frederick Ritter, Loessl. It is placed in a closed box, and does not require winding up nor to be moved, no external action being required to keep it going continuously. The watch is kept in motion by variations in atmospheric tension. The motor contains neither mercury nor any other liquid, all the parts of the watch being of solid metal. The watchwork is put in movement by a heavy weight, which remains always the same, and is appended to a roller. The function of the motor is then to provide that this weight, which acts as an accumulator, be kept constantly at the required

height. The chain which carries the weight roller is a closed chain, and goes on one side through the watchwork, on the other through a winding-up apparatus, which is regulated by the motor. A compensation pendulum is employed to secure regularity.

THE following are the resolutions relating to electrical standards adopted by the International Congress of Electricians at the sitting of September 22d, 1881:—(1) For electrical measurements, the fundamental units, the centimeter—for length—the gramme—for mass—and the second—for time—are adopted. (2) The ohm and the volt—for practical measures of resistance and of electromotive force or potential—are to keep their existing definitions, 10^9 for the ohm, and 10^8 for the volt. (3) The ohm is to be represented by a column of mercury of a square millimeter section at the temperature of zero Centigrade. (4) An international commission is to be appointed to determine, for practical purposes, by fresh experiments, the length of a column of mercury of a square millimeter section which is to represent the ohm. (5) The current produced by a volt through an ohm is to be called an Ampere. (6) The quantity of electricity given by an Ampere in a second is to be called a Coulomb. (7) The capacity defined by the condition that a Colcomb charges it to the potential of a volt is to be called a Farad. The adoption of these units for international use is to be preceded by a new and more careful redetermination of the ohm at the hands of the great physicists of all nations. And it is intended that this redetermination shall result in a standard for general adoption. Thus, remarks the president of the Royal Society, electricity will be the first of the practical sciences to be freed from all difficulties due to local standards; and it is to be hoped that this example may be followed in other sciences concerned with practical life.

IN consequence of the burning of a car during the autumn of 1879, on one of the railways of Baden, which was suspected to have been caused by nitric acid, Professor R. Haas, of Carlsruhe, was called upon by the Government to report whether the acid could produce combustion or not. In the experiments made to solve this question, the conditions which might be supposed to exist in freight cars containing nitric acid were imitated as far as possible. Small boxes of a capacity of ten to sixteen quarts were charged with variable proportions of hay, straw, tow, and blotting paper —all of which substances are used in packing— and placed within larger boxes, while the space between them was filled with hay or tow, to prevent too rapid a radiation of heat, because the experiments were to be conducted in the open air, and the outer box at the same time represented the walls of a railway car. The material contained in the inner box was now saturated with acid, and rather tightly compressed, so that when the cover was put on it was pretty well filled. At first reddish and afterwards whitish vapors were given off, finally a distinct smoke. On lifting the cover strongly glowing patches could be seen, which rapidly increased all through the contents, and which broke out in bright flames on access of free air or gentle fanning. With red fuming acid, or with acid of specific gravity 1.48, these results were obtained very rapidly, and within a few minutes. With ordinary acid of specific gravity 1.395, it required somewhat more time, and the action was less energetic in the beginning; but, in three different trials, after about twenty minutes, the same result was finally obtained, provided, the *Analyst* says, that the material was packed tightly in the box, and was thoroughly saturated in its successive layers.

GLYCERINE, with a few drops of alcohol, is better than most oils for oilstones. For sharpening very small tools, such as gravers, nearly all glycerine, or glycerine with the addition of but a few drops of alcohol, is best.

IT has long been taught that humid air acts as a conductor of electricity. Recent experiments of M. Marangoni throw doubt on this, for he finds that a Leyden jar heated so as to prevent condensation of moisture on its glass walls and thus arrest surface conduction, gives as long a spark as in the driest air. When, however, the precaution of heating the walls of the jar is not taken, the moisture condenses on the latter, and forming a thin film of water, causes a silent discharge which might be mistaken for a slow discharge through the conducting air.

THE addition of kerosene oil will greatly assist in preventing sperm oil from gumming. *Culver's Mechanics' Almanac* says:—"Thoroughly mix 100 parts oil with 4 parts chloride of lime and 12 of water. Now add a small quantity of the decoction of oak bark, to destroy all traces of gelatinous matter still remaining, and allow the impurities to settle. Next, agitate the clear part with a little sulphuric acid, settle once more and wash to remove the acid, which should never be permitted to exist in any oil used on machinery. If oil becomes rancid, boil it along with water and a little bicarbonate of magnesia for fifteen minutes or so, until it loses its power to redden litmus paper."

MR. HENRY HUSSEY VIVIAN has found that the one-thousandth part of antimony converts first-rate best selected copper into the worst conceivable, so bad as to be only fit for brass, and that one four-thousandth part makes it unfit for anything but inferior brass purposes and below the quality known as tough ingots. He discovered that one eight-thousandth part reduces it from "best selected" to "tough ingot" quality, and that one sixteenth-thousandth sensibly deteriorates the copper. Mr. Vivian states that one-thousandth part of nickel, cobalt, bismuth, arsenic, or phosphorus reduces "best selected" to "tough ingot," while nickel and arsenic in combination and mixed in the proportion of one five-hundredth makes copper unfit for brass, thus showing that two substances in combination may produce a far more hurtful effect than either of them separately.

THE following recipes for coppering and bronzing zinc are said to produce very good re-

sults:—Prepare a solution of 15 parts of blue vitriol and one of 19 parts of cyanide of potassium, then mix both solutions together. Incorporate this liquid well with 160 parts of pipe clay, and rub the resulting semi-fluid mass, by means of a linen rag, on the previously cleaned object. For bronzing, take 15 parts of verdigris, 19 of cream of tartar, and 30 parts of crystallized soda, reduce them to powder, and dissolve them in the necessary amount of water. Mix this liquid together with 160 parts of pipe clay, and then proceed as above directed. Another process is as follows:—Take 15 grammes of blue vitriol, 20 of calcined soda, and mix them well with 32 cubic centimeters of glycerine, and mix the paste obtained with 80 grammes of pipe clay. It is then ready to be applied as before stated.

A SIMPLE form of photometric balance has been invented by M. Coulon, who calls it an *a thermanous* photometer, as being acted on only by luminous rays. Its principle is that a radiometer, whose temperature is constant, turns solely under the influence of light. The apparatus consists of a radiometer bulb fixed in the middle of a cube-shaped metallic case, having four lateral apertures, closed with glass, through two of which light can be sent horizontally, traversing the bulb while the two others allow observation of the bulb. The case is filled with water, which, through four vertical tubes, screened from the bulb, and surmounting spirit lamps, is heated to a temperature above that of the radiant heat of the sources to be measured—in practice about 100 degrees suffices. The bulb contains, *in vacuo*, a disc movable round a vertical axis; the half disc on one side of this axis being black on its two faces, the other white. When a single source of light acts on the bulb from one side, it attracts the white half and repels the black, so that the disc turns edgewise to the light, and presents one side to the observer. If another equal light act simultaneously on the other side and at the same distance as the first, the counteraction results in the disc presenting its sides to the light, its edge to the observer. Where unequal lights are compared, one may always, by shifting one of them, bring the disc into the second position just specified, and by then measuring the distances, ascertain the ratio of the intensities.

IN a report on riveting in locomotive boiler works, made by a committee of the American Master Car Builders' Association, we find the following. The operation of "driving" rivets consists in placing a set on the end of the rivet, and sledging it down to form the head, the operation requiring two men to sledge, one to hold the set, one to manage the holder, and a boy to heat the rivets. "The rivet is not struck direct by the sledges at any time during the operation of driving, but the head is formed entirely by driving the set down squarely on the end of it. To drive a rivet requires about twenty-four blows with the 9 lb. or 10 lb. sledges at the rate of about eighty blows per minute; a flatter, with a face about 1¼ in. square, is then placed on the lap alongside the rivet, and given five or six blows to close the sheets together; the set is then placed on the rivet head again, and given five or six more blows and the rivet is finished; the whole operation of driving requiring about thirty-five seconds of time to the rivet. In practice we find that a riveting gang will drive in the seams of the shell of a boiler, on an average of thirty rivets per hour, or 300 per day, and in the seams of the fire box, in throat and back sheets, dome, mud ring, braces, &c., an average of about twenty-two rivets per hour. This includes the time necessary for taking out bolts, drifting holes, adjusting the tools and the work. In hand riveting two riveters will drive, on an average, taking the whole boiler, only about 125 rivets per day, or 12½ per hour."

THE phenomena of the bursting of bubbles has recently occupied the attention of M. Plateau. When a bubble bursts it disappears almost instantaneously, leaving behind it a multitude of small liquid drops. The order of the phenomena is described as follows: The bubble begins to burst at one point, the film rolling away in a circle around the opening, and its edge becoming a rapidly-enlarging liquid ring. This ring draws itself together into segmental portions, which ultimately become small spherules. At the same time the contraction of the rest of the bubble causes a rush of air through the aperture, and blows off the spherules into the air with a kind of small explosion. The phenomena are best observed by blowing a bubble of glyceric solution upon an iron wire ring, and then bursting it at the top by touching it with a needle whose point has been dipped in oil.

AT the meeting of the Chemical Society on the 15th inst., Mr. V. H. Vetey read a paper "On Some Higher Oxides of Manganese and their Hydrates." The author prepared pure oxides of manganese containing less than 1 per 1000 of potassium and 1 per 6800 of calcium. He heated the higher oxides in currents of nitrogen and in pure hydrogen, estimating the water evolved and the loss of weight of the oxide. The temperatures used varied between 80 to 200; a few experiments were made at higher temperatures. At certain points in the thermometric scale the manganese compound remained unaltered on continued heating at that temperature. On this ground the author concludes that a definite oxide or hydrate was formed. On raising the temperature a further loss of water or oxygen takes place, until another point in the thermometric scale is reached, at which the manganese compound again remains unaltered on continued heating at that temperature. The author concludes that another definite oxide or hydrate is formed, and so on. The author determined the specific gravity of some of these oxides. He concludes with some theoretical discussion as to the probability of the metallic oxides having formulæ much more complicated than those usually assigned to them.